Instruments

THE MAGAZINE OF Measurement and Control

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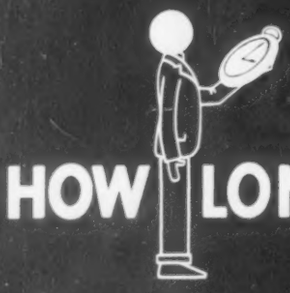
No. 4



TAG

RECORDING PRESSURE GAGES

TAG Recording Pressure Gages supplement the performance of indicating pressure gages with written records you need for reference.

It is not enough that pressure losses may be apparent when the conventional pressure gage is looked at . . . here's an instrument that gives you a continuous record of not only the magnitude of the pressure change, but WHEN it took place and for WHAT PERIOD of time.

Just translate that type of permanent information into terms of process efficiency and dollar saving operation and you can quickly visualize the points in your plant where these TAG Recording Pressure Gages belong right now.

The price of these carefully designed, accurately calibrated TAG Instruments is moderate. They are available in 3 sizes utilizing 9" - 10" and 12" charts . . . Write for descriptive Catalog No. 1060-I which also describes TAG Recording Thermometers.

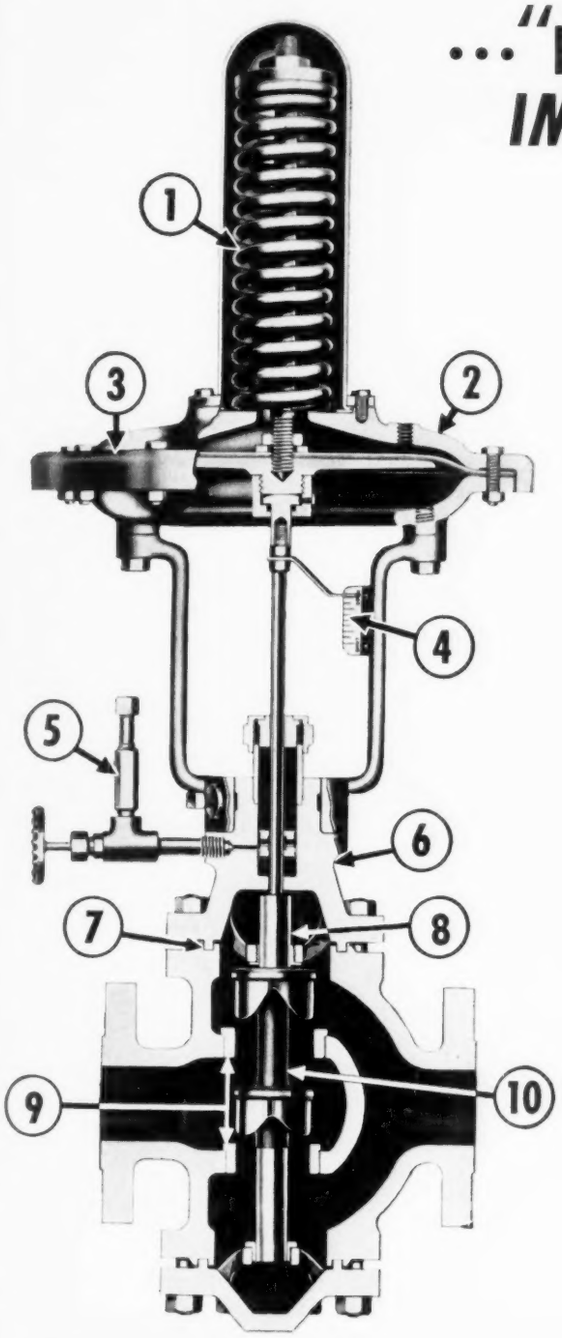
C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

TAG TAGLIABUE BROOKLYN N.Y.

Make a check on all 10!

..."plus-value" features of the *IMPROVED* Stabilflo Valve



1 Fully enclosed alloy steel spring has permanent tension characteristics, needs no adjustment after leaving factory.

2 Stabilflo diaphragm motor has excess power to assure positive movement. Suspended, "floating power" design eliminates need for guides, cuts friction.

3 Shoulder protects diaphragm from grease and dirt.

4 Travel indicator shows position of plunger. *Note that high-lift construction gives twice the movement for same air pressure change as ordinary valves.*

5 Valve stem lubricator cuts friction in stuffing box. Deep packing space prevents leakage with low unit packing pressure.

6 Valve bonnet and stuffing box are integral for added strength and tightness.

7 Tongue and groove connection between body and bonnet assures perfect alignment, cuts possibility of friction.

8 Plungers have large-area top and bottom guides of polished stainless steel.

9 Stainless steel seat rings give freedom from corrosion, long life. (Other materials available.)

10 *Wide-range, equal percentage, V-Port plunger* has a rangeability of 50 to 1, giving equal percentage increases in flow for equal amounts of valve lift from 2% to 100% capacity.

(This type of plunger recommended for all but highly exceptional control applications - parabolic plug and wide-ratio plug types also available.)

FOXBORO

REG. U. S. PAT. OFF.

RECORDING / CONTROLLING · INDICATING

Instruments

Certified ACCURACY RESPONSE

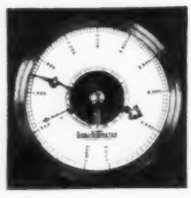
TEMPERATURE · LIQUID LEVEL
PRESSURE · FLOW · HUMIDITY

These new Stabilflo controlled valves combine accurate response characteristics with a rugged construction built to stand punishment. For complete details write **The Foxboro Co., 46 Neponset Avenue, Foxboro, Massachusetts, U.S.A.**
Branch Offices in 25 Principal Cities.

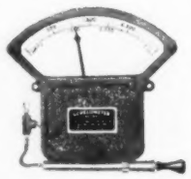
WRITE FOR BOOKLET 789

LIQUID
A$$ET$
Controlled

LIQUIDOMETERS provide continuous dependable and accurate knowledge of liquid levels.



LIQUIDOMETER—Remote Reading Gages. Automatically indicate or record liquid levels. No pumps, valves or auxiliary units required to read them. Balanced hydraulic transmission system ingeniously compensated for temperature variations on communicating tubing. Accuracy unaffected by variations in specific gravity. Models are available for remote signals, automatic control of pumps, etc. Direct reading models available where remote reading is not required.



LEVELOMETERS — Dial Type Hydrostatic Gauges operate on hydrostatic principle of establishing balance between head of liquid and an indicator. Dial indication featured. No liquid to expand or contract and create errors. One dial can be arranged to gauge a group of tanks.

Approved by Underwriters Laboratories and similar bodies for gauging hazardous liquids.

Write for details

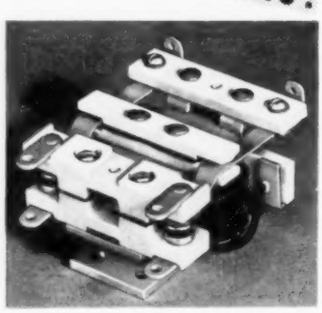
THE LIQUIDOMETER CORP.
36-27 SKILLMAN AVE. LONG ISLAND CITY, N. Y.

ACCURACY PLUS AT LOWER COST

...WITH THESE SENSITIVE AC OR DC RELAYS!

Whether your application need is for automatic control, changeover, keying, etc., you'll get greater efficiency and dependability when your assembly includes Kurman relays.

This new "25 relay"—rugged, compact, foolproof—has a low power consumption of 1.5 watts and high power output of 2,000 watts. Developed to fill the need for a high quality medium-duty relay at low cost. Coin silver contacts—¼" diam. Alsimag non-hygroscopic insulation, cantilever spring action, self cleaning wipe.



Cut production as well as experimental costs specify Kurman relays for the next job. Write for descriptive literature; no obligation.

KECO KURMAN ELECTRIC CO. INC
241 Lafayette Street, New York, N. Y.

Instruments
THE MAGAZINE OF MEASUREMENT and CONTROL

Vol. XIII APRIL 1940 No. 4

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Courtesy Westinghouse Elec. & Mfg. Co.

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Instruments

THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

A Comprehensive Course

EIGHT years ago, in the preface to the first book on Instrumentation, it was predicted that there would be Instrumentation courses in the majority of technical schools and chairs of Instrumentation in universities. Little by little, this is coming true. Today the majority of technical schools teach at least a few Instrumentation subjects. And now it seems (from a recent letter ordering twenty-six copies of "Fundamentals of Instrumentation") that a nearly complete course is being inaugurated:

THE OREGON STATE COLLEGE
CORVALLIS, OREGON

. . . Herewith I am enclosing a preliminary copy of the course outline which I prepared for use of our course revision committee. While this probably is not complete, it will serve as a rough index of what I expect to include in the course. In our laboratory we have many indicating and recording instruments. . . .

S. H. GRAF, Professor of Mechanical Engineering

[Enclosure]

ME 476. Industrial Instrumentation. Three hours.

1. *Review of basic standards.* Length, mass, time, temperature, &c.

2. *Elements used in Measuring Devices.* Direct weighing, displacement, inferential mechanisms, orifices, manometers, bimetals, Bourdon tubes, expansible units, thermocouples, photocells, relays, contacts, galvanometers, resistances, potentiometers, recording and integrating mechanisms. Schemes for actuating remote devices.

3. *Industrial Measuring Instruments.* Indicators, recorders, and integrators. For pressure, time, speed, temperature, flow, liquid level, gas composition and heating value, solution concentration. Length comparators, contour projectors, smoothness gages. Noise and vibration measurements.

4. *Process Control.* On and off. Step by step. Continuous modulating. Anticipatory. Safety devices.

5. *Examples from Industry.* Manufacture, petroleum, gas, heat treatment of metals, air conditioning, power plants, paper, lumber drying, automatic inspection.

6. *Precision of Measurement and Control.* Manual *vs.* automatic. The personal element. Accuracy of instruments. Scale ranges. Sampling in inspection. Statistical analysis of data.

7. *Calibration and Maintenance.* Periodic inspection and checking. Calibration standards available. National Bureau of Standards. Organization of maintenance.

War and Peace Value of Instrumentation

APRIL 6 (anniversary of U. S. entry in First World War) is Army Day and this page in the April '35, '37 and '39 issues was devoted to patriotic preachments. This year it really isn't necessary, is it?

Instead, brief answers to frequent questions:

Our industries could eventually produce the equipment of a mechanized and motorized force adequate to meet a major emergency; but most facilities are so unprepared to produce such matériel that in the event of a sudden emergency (the only kind nowadays) they would find themselves under alien masters before they could get started.

Instruments readers can render effective service by doing their own work: by constantly extending the fields of industrial instrumentation.

This is particularly true in the fields of automatized production processes, automatized inspection and automatized testing. Specifically, automatic gaging of items required in large quantities is the most crying need—and it is one of the industrial preparedness problems which *Instruments* readers are well qualified to solve.

The applications of automatic gaging divide themselves into two distinct classes:

1. Continuous gaging—of materials, such as wires, sheets, etc., continuously passing through the measuring instrument.

2. Part-by-part gaging, nearly always with automatic selection and rejection, sometimes with automatic classification into a plurality of acceptable grades between the reject bins at both extremes.

Readers who know of interesting automatic inspection devices are asked to write to the editor.

Finally, bear in mind that these needs (automatized processes, inspection, etc.) are *peace-time* needs. If all of us instrumenticians do our jobs well, we shall contribute greatly to the return of good times and to the establishment of permanent prosperity in this country. And a permanently prosperous America is one of the requisites for a peaceful civilized world.

To Readers in Chicago District

You are cordially invited to attend a meeting to discuss the formation of the Chicago Chapter of the American Society for Measurement and Control to be held in the Home Service Auditorium of the Peoples Gas, Light and Coke Company, 122 So. Michigan Ave., Chicago, Illinois, on **Tuesday, April 16th,** at 8 P.M.

Chicago Committee Pro Tem

EARL C. RIEGER, International Harvester Co.
RICHARD SCHOENFELD, Wheelco Instruments Co.

That Settles It!

IN our October 1939 issue we published R. K. Hellman's article, "An Audio Frequency Spectrometer" which was awarded the $100 second prize in the 1938 Instrumentation Contest. Since then we received communications pointing out similarities between that article and one in *Reports on Advances in Communication Engineering* published in June 1937 by Siemens & Halske, Berlin, Germany. Other readers—who did not write us—no doubt noticed these similarities.

If our own gullibility was the only point involved, the matter would not have to be aired on this page. However, the Jury of Award comprised (in addition to your editor):

Lyman J. Briggs, Director National Bureau of Standards;
John J. Grebe, Director Physical Research, Dow Chemical Co.;
R. J. S. Pigott, Head Engineering Dep't., Gulf Research;
P. T. Sprague, Chairman Industrial Instr. Section, S.A.M.A.

All five of us read all manuscripts and agreed that Mr. Hellman's manuscript deserved the second prize. Mr. Hellman's association with the development he described was apparent from the fact that he enclosed, with his manuscript, original photographs and drawings. The photographs, examined through a magnifying glass, did not show the characteristic pattern which betrays photographs of half-tone illustrations. The drawings were not process prints but India ink originals. Moreover, the Contest Rules (published in our August 1938 issue) did not require that each entry be a first disclosure such as a patent application but "a manuscript not hitherto published." Nevertheless Richard Rimbach, Conductor of the Contest, wrote Mr. Hellman and received a conclusive reply from which we are privileged to quote—thereby giving Mr. Hellman, as is his due, the last word:

Under the Rules of the Contest and in particular under Rule 5, I submitted an original article entirely written and conceived by myself as the result of my personal participation in research and development . . . in the laboratory of the Siemens & Halske Co. During the progress of this joint research work, I made a number of original contributions to the final form of the device. . . .

I have never seen the article by Vogel and Hennecke which you mention in your letter, which gentlemen were not in any way, to the best of my recollection, connected with this research project.

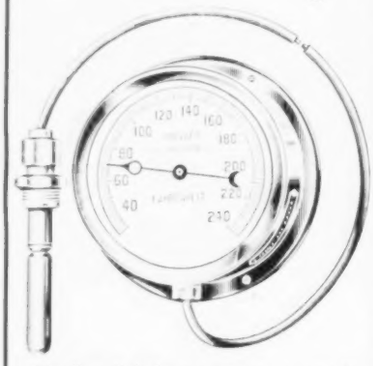
I had no recourse to any work by any other person in the preparation of the article submitted to you but relied entirely on my own notes and knowledge of the theme.

MOELLER
PRECISION GRADE INSTRUMENTS

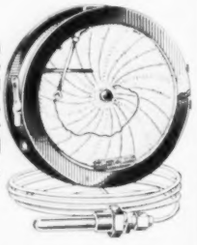
★

Our mercury thermometers are made with the Moeller Glass Red Reading Column which makes them easy to read under varying light conditions, at a considerable distance and over a wide range.

★



Moeller dial thermometers are made in various scale ranges up to 1000°F. or equivalent in both Metal and Phenolite cases.



Moeller recording thermometers are likewise furnished in various ranges up to 1000°F. or equivalent. Round and square cases, as preferred.

Also HYGROMETERS
RECORDING PSYCHROMETERS
BAROMETERS HYDROMETERS
MARINE INSTRUMENTS, ETC.

Write for catalog.

MOELLER INSTRUMENT COMPANY
132nd STREET and 89th AVENUE
RICHMOND HILL NEW YORK

Sales Representatives in Principal Cities

THE MONTH'S NEW INSTRUMENTS

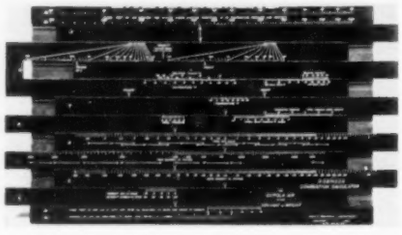
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Directional Undervoltage Relay

New "GGP" directional undervoltage relay for protecting generators against motoring is said to combine high sensitivity and nonbouncing characteristics of an induction-cup polyphase directional element with the accurate adjustable timing of an induction-disk undervoltage element. New relay's undervoltage element is normally energized through contacts on the directional element. These remain closed unless there is a reversal of power when generator starts motoring. If this occurs, contacts open and de-energize the undervoltage element, which in turn closes its contacts after a delay dependent on the time setting. These contacts are in series with another set on directional element, so that timing function is independent of voltage variations. Tripping can occur only for an actual reversal of power maintained for the predetermined time interval. The return of power to its normal direction at any time during this interval prevents undesirable tripping. New relay is housed in a 5½" x 12" universal case. Standard model has a sensitivity of 0.5% of full-load power.—*General Electric Co., Schenectady, N. Y.*

Calculator for Cupola Combustion

Foundry troubles such as mis-runs, blow holes, poor grain, variable carbon, etc., are caused by faulty relationship between the air and coke; and ordinary calculations to keep this constant are said to take too long to be of any value. New Robinson Combustion Calculator permits making computation in less than one minute. Variables involved are ash in coke, pounds coke in "basic coke charge," pounds iron per charge, rate of melting, barometric pressure, cupola pressure, temperature of air, humidity, and the equilibrium between the CO_2, CO, carbon and iron at the temperature and pressure involved. The same calculator is used for all sizes of cupolas, is said to require one-half hour of instruction.—*The Louis G. Robinson Laboratories, 219 McFarland St. Cincinnati, Ohio.*



Pocket CO_2 Tester

Body of new "Model 800 Carbon Dioxide Indicator" is of clear transparent plastic; its base is chromium-plated. Designed to give consistent results regardless of user's previous experience, it requires no skill for its operation, which is as follows: (1) Make rubber tubing connection to flue or stack; (2) pump gas sample into body by a dozen strokes of aspirator bulb while plunger is held down; (3) raise and then lower absorbing unit. Plastic material is unaffected by absorbing medium used. Plunger valves (patented) and all metal parts that come in contact with solution are of stainless steel. Solution "will not freeze." Instrument cannot be injured if overturned; and plunger and vent close automatically so that no solution can be lost. Carrying case (not shown) has compartment for draft gage and flue-gas thermometer, both of which can be furnished by same manufacturer.—*F. W. Dwyer Mfg. Co., 565 W. Washington Blvd., Chicago, Ill.*

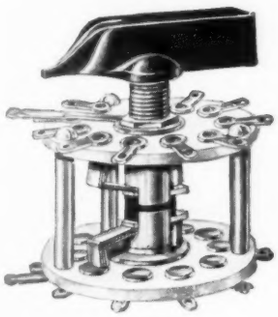
Pinchcock

New "Castaloy" Pinchcock is said to be a distinct improvement over devices previously available for shutting off and releasing the flow of liquids through rubber tubing. There are only three parts—two "Castaloy" pieces including the jaws and finger grips, and a spring. By pushing finger grips with thumb and forefinger, jaws are opened to accommodate rubber tubing to be pinched. New pinchcock can be applied at any point on tubing and quickly released or removed. The broad faces of the jaws (⅜") and their depth (⅝") eliminate both the "single-line" application of pressure and the possibility of leakage. The jaws always move in parallel alignment and there is a uniform straight-line squeeze when they apply pressure to the tube. Available in two strengths: regular and heavy duty; identical in appearance but one has a much stronger spring than the other. Regular is sufficiently strong to close ¼" heavy-wall pure rubber tubing; heavy-duty will close tubing of the size and composition usually employed for gas and water connections.—*Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

FOR *Permanent* LOW CONTACT RESISTANCE, *use the*

SHALLCROSS

ROTARY SELECTOR SWITCH

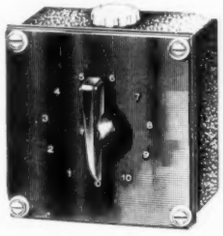


Particularly designed for use with the Thermocouple and other instrument circuits, also to control circuits such as found in high grade electrical apparatus.

Made with a very superior ceramic switch plate known as "steatite", and has *eleven solid "fine" silver contacts and contact arms.* The average contact resistance in this switch is .00075 ohms or less. Supplied with more or fewer contacts, with or without stops, shorting (bridging) or non-shorting.

COST SLIGHTLY MORE—BUT *WORTH MUCH MORE* BECAUSE THEY LAST LONGER, ARE MORE ACCURATE.

Also furnished *enclosed*—mounted on a beveled bakelite panel with etched dial and housed in a cast aluminum box.



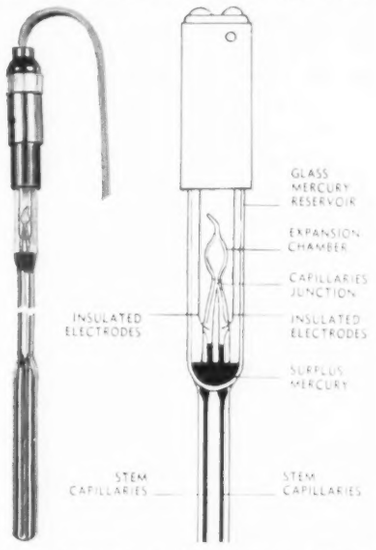
These boxes are also available with Shallcross No. 551 Switch, employing brass contacts and phosphorus bronze contact arm.

Write for Switch Bulletin No. 141-HO

SHALLCROSS MFG. CO.
Instruments — Resistors — Switches
COLLINGDALE, PA.

Thermoregulators

New "Mere-to-mere" line of thermoregulators is so named because of radically new design whereby circuit is closed when two separate mercury capillary columns rise to junction point and circuit is opened when these two columns fall below this point.



Each instrument is, in effect, a pair of modified Beckmann type thermometers — even the bulb being divided by a partition (faintly visible in photograph illustration). Electrodes are sealed into capillary bores below junction, so that circuit is always open when columns pass electrodes. Thermoregulators are available in straight form (approx. 12½" long) and in angle form (horiz. and vert. legs each approx. 6" long). Bulb length is approx. 3½" and consequent sensitivity is within 0.1°F. Lag is minimized by doing away with glass insulating shell. Setting point is adjustable up to 700°F. Electrical connection is of detachable bayonet type. — *Philadelphia Thermometer Co., 915 Filbert St., Philadelphia, Pa.*

Modernized Mortar Grinder

"Fisher's Improved Mortar Grinder" is said to be superior in many respects to previous model. It meets requirements that pestle should move over the entire grinding surface and in different paths, contents should not spill over the sides, everything about it should be adjustable, the mortar should be emptied and cleaned without unclamping, and all liability of contaminating the sample eliminated. In addition, elimination of exposed gears, protection of motor and moving parts from the sample and dust, application of a known optimum pressure on the pestle with subsequent elimination of clamp and spring adjustments, permanent lubrication of worm and worm gear, more silent operation, and an attractive appearance. Casting that houses the motor and gears is about 18" long, 12" wide and 6" high. On it are mounted the revolving table to which the mortar is clamped, the pestle support and pestle driving mechanism. Switch is located on front of housing. Mortar is held securely on revolving table by means of three bolts adjustable for mortars of different heights and diameters. Since revolving platform has a hub which fits over a pin on motor shaft, it is a simple matter to lift off this platform with the mortar attached for brushing out the sample. This obviates the necessity of removing the bolts each time mortar is to be emptied or cleaned. Pestle and pressure weight are on a hinged arm that can be lifted when the mortar is to be removed. Other features are that movement of pestle can be regulated to suit size of mortar, and pestle can be readily removed. — *Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

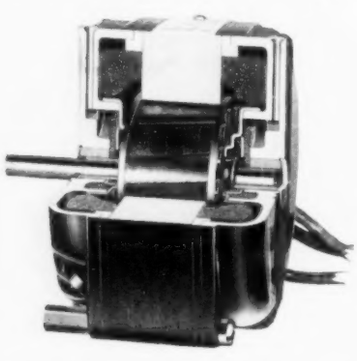
BAILEY METER COMPANY
1041 Ivanhoe Rd., Cleveland, Ohio

Double-pivot Galvanometer or Microammeter

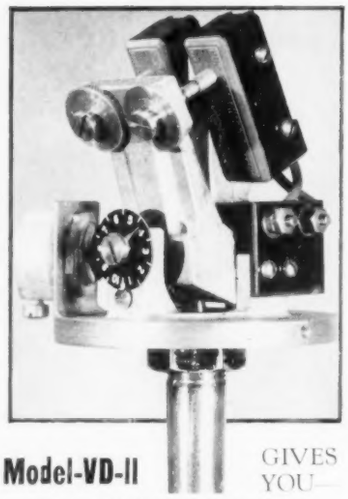
Designed for wide serviceability and harder usage than the suspended-coil type of galvanometer, Models "G-6" through "G-2150" double-pivoted, moving coil instruments are recommended for laboratory and workshop. Scale has 60 divisions; 30-0-30 mm. as a galvanometer, 0-60 mm. as a microammeter. Available in seven resistances: 6, 12, 33, 150, 350, 900, and 2150 ohms. The 6-ohm coil instrument has a current sensitivity of 3.3 ma./mm.; others proportionately higher. Triplett movement has special cobalt magnet with cut pole pieces. Resultant high flux density, together with "very light" moving system, mirror scale, and 4¼" knife-edge pointer, make possible this high sensitivity. New instruments are said to have a high zero stability, a comparatively short period and to be comparatively unaffected by vibration. System is said to be highly insulated. Beside top cover of laminated Bakelite, binding posts are insulated by a special Bakelite panel. Instrument comes in a dust-proofed portable mahogany case, base 7" × 4⅝"; but can be mounted or built into apparatus.—*J-B-T Instruments Inc., 441-C Chapel St., New Haven, Conn.*

Instrument Motor

New "Type K" motor for continuous-operation instrumentation devices is 2⅝" wide and high, 1⅝" long excluding ⅝" shaft extension. It weighs less than 1½ lbs.



Designed as a capacitor motor, it can be supplied with three different windings — synchronous capacitor, nonsynchronous capacitor, and dynamic braking capacitor. Standard ratings on 110 volts 60 cycles are 1/1500 hp. at 1800 rpm., 1/1000 hp. at 1700 rpm. and 1/1500 hp. at 1200 rpm. Motor input is 8 watts or less. Normally three leads are brought from the motor, and it can be reversed, even when running, by means of an s-p. d-t. switch. Capacitor furnished with motor has a bracket for separate mounting. Motors wound for lower voltages can be built on order. On higher voltages a transformer is necessary. Motors for lower frequencies can be supplied. Sleeve bearings are standard, ball bearings optional. Windings will withstand stalling indefinitely and all NEMA requirements for temperature rise are met. Motor is approved by the Hydro-Electric Power Commission of Ontario.—*Bodine Electric Co., 2254 W. Ohio St., Chicago, Ill.*



Model-VD-II GIVES YOU—

FLOATING CONTROL,
STEP CONTROL,
HIGH or LOW LIMIT CUTOUTS

SPECIAL MOUNTING in
EXPLOSION PROOF HOUSINGS

Temperature Range Minus 100 to 1200°F.
Other models to 1400°F.
Differentials ± ¼ deg. to ± 5 deg. F.
Will give accurate control in ovens, tanks, incubators, water baths, dryers, chemical processes, and air ducts.

BURLING INSTRUMENT CO.
239-241 Springfield Avenue
NEWARK, N. J.

Thermometers
Hygrometers
Psychrometers
Hydrometers

Several hundred types and varieties of instruments are described in new Catalog 110, but since ALL of them are produced in our own factory under our own experts' supervision, the best materials and high-grade workmanship characterize EACH of them.

Our customers find special satisfaction in the choice of FOUR different styles of thermometer glass: 1. White enamel back; 2 yellow enamel back; 3. Hespi; 4. red-reading mercury.

TWO WIDELY USEFUL NUMBERS

(Left) No. 169. For pressure-cooking processes, with two scales: 170-270°F. and 0-30 lbs. pressure. 9" scale length.

(Right) No. 326. Max. & min. registering thermometer in 12" shelter type copper case. Approx. range minus 40 to 120°F.

Weksler Thermometer Corporation
535 PEARL STREET NEW YORK, N. Y.

Diaphragm-motor Valves

New line of "Stabilflo" controlled valves is designed for improved response to the commands of a control instrument. When equipped with a wide range V-port plunger, valve has a rangeability of 50 to 1. When this valve is lifted off the seats, initial clearance flow is 2%. From this 2% flow to 100% flow, valve gives equal percentage increases in flow for equal amounts of valve lift. This V-port plunger is screwed and pinned to valve stem and designed for easy field reversal. In addition to this V-port valve plunger, a parabolic plug type and a wide ratio turned plug type are also available for exceptional control applications. Body and plunger are designed for high lift, in order to achieve wide-range flow characteristics required by modern automatic controllers. High-lift construction is said to afford twice the movement of ordinary valves for the same air pressure change, and accuracy of positioning is said to be twice as great. Operating unit in the complete line of valves is "Stabilflo Floating Power Motor." Suspended construction of this motor obviates need for guides and anti-friction bearings. Motor may be removed without disturbing motor adjustments or relation between valve and motor. It has been designed with sufficient excess power to enable it to meet all operating conditions. Friction is minimized in the one-piece bonnet and stuffing box assembly. Tongue-and-groove connection assures alignment of body and bonnet. Use of a deep lubricated stuffing-box and polished stainless steel valve stem minimizes stuffing-box friction. Stainless steel gland nut and packing follower need never be more than finger-tight — eliminating trouble from rusty threads. A ring type packing is used for tighter sealing. Plungers are provided with top and bottom guides of polished stainless steel; guiding surfaces large in both diameter and depth insuring freedom from excess wear. Spider construction of guide supports prevents deposit of sediment that would interfere with operation.—*The Foxboro Co., Foxboro, Mass.*

Strip Resistors

New "Blue Ribbon" resistors depart from conventional tubular form, the wire being space wound on "Steatite" core of elliptical cross-section having maximum thickness of ¼". Standard mounting method is by means

of an aluminum through-bar which distributes heat. Among advantages claimed are "higher wattage rating per unit space requirement, lower inductance, resistor and mounting integral unit." Available in 30- to 75-watt nominal ratings; resistances from 0.10 to 70,000 ohms.—*Hardwick, Hindle, Inc., 49 Herman St., Newark, N. J.*

JAGABI *"Lubri-tact"*
RHEOSTATS

have a graphited carbon lubricator associated with the contact brushes. Eliminates scratching and abrasion—gives smoother operation and a better contact. Makes Jagabi Rheostats *better* rheostats.

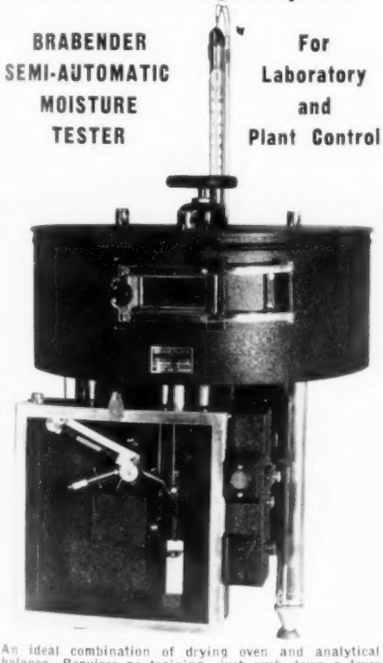
Write for Bulletin 1620-I which lists new lower prices.

JAMES G. BIDDLE CO.
Electrical Instruments
1211-13 Arch Street Philadelphia, Pa.

Moisture Testing Simplified

BRABENDER SEMI-AUTOMATIC MOISTURE TESTER

For Laboratory and Plant Control



An ideal combination of drying oven and analytical balance. Requires no training—just push down a lever and read the moisture loss from an illuminated dial—directly in percentages.

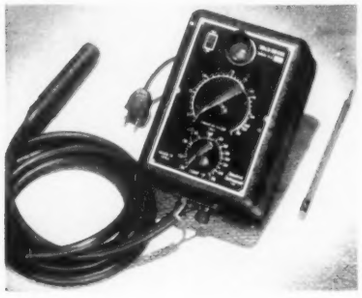
Accuracy—1/20th of one percent. Capacity—Ten 10-gram samples. Temperature Range—85° C.-175° C. Moisture Range—0%-100%. Heating Capacity—750 Watts. Operating Current—110 volts, 60 cycles, AC (25 cycles if required). Heating up time—5 to 10 minutes.

Write for pamphlet

BRABENDER CORPORATION Rochelle Park New Jersey

Conductivity Bridge for NaCl Content

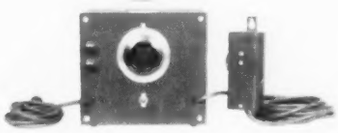
New addition to "Solu-Bridge" test instruments is "Model RD-4," designed for use in chemical laboratories, industrial plants, boiler rooms, municipal water systems, and "wherever washing and rinsing operations are performed." It is said to be especially useful in checking concentration of water in evaporating chambers and in



determining carry-over from treating operations where electrolytic materials are used in processing. Instrument operates on electrolyte conductivity principle. To operate, plug line cord into a 110-volt 60-cycle outlet and dip conductivity cell (furnished with instrument) into the water to be tested. Indicator dial is then rotated until shadow in "magic eye" type cathode-ray tube is at a maximum. Concentration in grains per gallon is then read directly from the dial. Range is 1 to 500 grains per gallon and temperature compensation covers a range from 64° to 190°F.—*Industrial Instruments Inc., 156 Culver Ave., Jersey City, N. J.*

Automatic Controller for Photographic Exposures

To eliminate inaccuracies of trial-and-error method of measuring photographic time exposures, new "Totalux" is for use in timing exposures from one to twenty



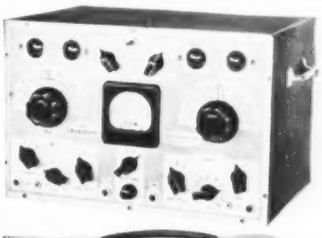
minutes in work requiring close limits. (Photoengraving and lithography, among other applications, necessitate compensation for light-intensity fluctuations, particularly when carbon arcs are used.) Totalux controls exposure by automatically increasing or decreasing total time according to variations in intensity of light source. It consists of a light-sensitive element and a control box, on the front of which are a switch and an adjusting dial. Light-sensitive element is placed to receive light from the source being used for photographic exposure. Adjusting dial is calibrated in 100 divisions; once the number of divisions corresponding to standard exposure time has been determined, dial may be set to this number regardless of intensity of light source. At end of corrected exposure time, an auxiliary relay operates contacts which either turn off the light or sound an alarm. Automatically adjusted duration is proportional to time and light intensity. Although designed for 115 volts and 50-60 cycles, Totalux can also be adapted to other frequencies and voltages. Weighing about 16 lbs., equipment measures about 8" × 10" × 7".—*General Electric Co., Schenectady, N. Y.*

For Modern Radio $ervice... the *Big Three* by RCA

More equipment for your money... more money for *you* from your equipment

With RCA Test Equipment, every step you take in checking a set is a step on which you collect in cash. The Rider CHANALYST revolutionized servicing. The Rider VOLT-OHMYST is the only instrument of its kind. The RCA SIGNALYST has revised all opinions on dollar value in a signal generator.

Designed to minimize obsolescence, the RCA Big Three put the dollar sign in Service. Get more equipment for your money... and get more money from your equipment. Invest in the RCA Big Three Now.



1. THE RCA RIDER CHANALYST ... The Original Signal Tracer that Revolutionized Servicing! Net price $107.50

2. THE RCA SIGNALYST ... The Most Modern Signal Generator. Range—100 Kc to 120 Mc, 60 in fundamentals. Net Price $107.50

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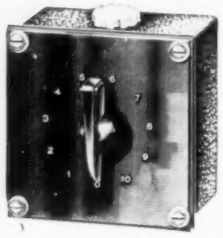
Over 335 million RCA Radio Tubes have been purchased by radio users. In tubes, as in parts and test equipment, it pays to go RCA All the Way.

RCA *Test Equipment*

RCA Manufacturing Co., Inc., Camden, N. J.
A Service of the Radio Corporation of America

Selector Switches

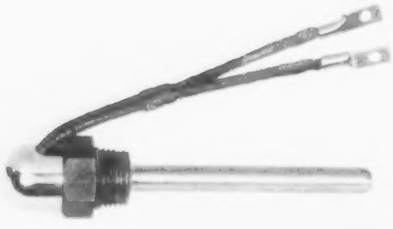
New "No. 551" enclosed solid-silver contact rotary selector switch has eleven contacts, two sections. Switch is mounted on a beveled Bakelite panel and housed in a cast



aluminum box with an etched dial. New "No. 537" switch is particularly designed to work as a selector switch in connection with thermocouple and other instrument circuit must be broken in a small switch." Ceramic switch plate is "Steatite." Contacts and contact arms are solid silver. Extremely low contact resistance is claimed.—*Shallcross Mfg. Co., 19 Jackson Ave., Collingdale, Pa.*

Thermocouple Fixtures

"Model TCF-1" includes thermocouple and fixture for Diesel engine exhaust temperatures, etc. 8" thermocouple is chromel ex. alumel, asbestos-insulated and painted with



asbestos fireproof paint. Nickel well is approx. 3½" long, with ½" pipe thread connection. "Model TCF-2," same except that 3½" well is copper, is designed for rapid determination of water temperatures, etc., where no oxidizing atmosphere is present.—*I-B-T Instruments, Inc., 141-C Chapel St., New Haven, Conn.*

Soil pH Tester and Manual

General laxity in applying scientific methods, on the part of "small" and amateur gardeners, probably is due to the lack of a simple, convenient method of determining soil condition, together with difficulty in obtaining specific instructions on how to treat soil. For making this simple test quickly, new Fisher "Alkacid" Soil Tester, together with "Alkacid Soil Test Manual," is being made available. Tester is similar in appearance to maker's Alkacid Tester for making approximate pH measurements. It is a transparent molded plastic container holding a 100-test supply of Alkacid Soil Test Ribbon and is supplied with a color chart with yellow, orange and plum colors. To conduct a test an extraction of the soil is made according to directions in manual, a piece of the Soil Test Ribbon is dipped into the extract and the color of the ribbon is then compared with the colors on the chart. Ribbon is sealed from atmosphere by the plastic container and a special rubber gasket so that it will not deteriorate. Manual lists the soil preferences of more than 300 plants, shrubs, vegetables, trees, flowers and fruits and gives instructions as to how soil is to be treated if it is too alkaline or too acid.—*Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

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ACCURACY 2% OF FULL SCALE
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Our thermocouples will meet the most rigid requirements. Write your requirements to—

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Small wood screws in brass, steel, etc., turned from the bar.

BLACK GRINDING DISCS

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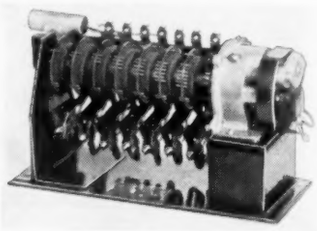
P. O. BOX 233, SIDNEY, NEW YORK

Multiple-circuit Timer

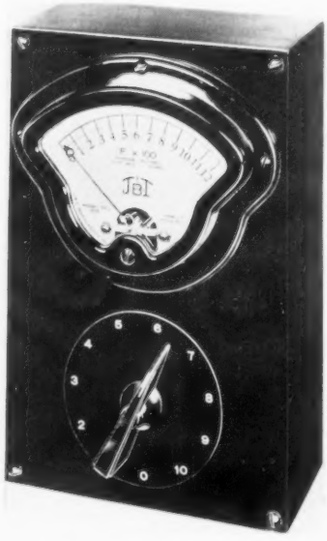
New "Type 101," multiple-circuit timers were designed for industrial application although serving also to round out maker's line of sign-animation controllers. Model



illustrated has seven disks mounted on a square shaft driven by a synchronous motor; each disk carrying from one to ten pins on its periphery, for actuation of mercury-to-mercury contact type switches. Timers are said to be quiet, easy running and self-lubricating. — *Emra D. Bacon, 1311 Brookhaven Ave., Cleveland, Ohio.*

Diesel Engine Pyrometer

"Model 50-JS," comprising "Model 50-J" pyrometer and "Model S-11" rotary selector switch, is primarily designed for measuring exhaust and water temperatures of Diesel



engines; is fully compensated for ambient temperature and copper error, 0-1200°F. range on 3⅛" scale, 20° per division, readable to ½ division. Others available. Cast aluminum case, approx. 7⅝" × 4⅜" × 2⅝" thick, houses switch and Triplett milliammeter movement, which is first enclosed in a molded instrument case. Overall thickness from top of switch knob to base of aluminum case is approx. 3⅛". Mounting studs for switchboard use, or special attachment for wall mounting, are optional. Thermocouple extension leads are normally connected to switch through bottom of the case; back connection on special order. Selector switch, for ten or fewer thermocouples, is said to have low and constant contact resistance by use of silver alloy studs and contact springs; and high insulation resistance between contact studs and ground by use of ceramic material for mounting studs and insulating one circuit from the other. "Model 50-J" pyrometer is available without switch, in molded case with flange for switch mounting; case front dimensions approx. 4¾" × 4". Entire "50-JS" can be mounted with only case front, dial knob, and numerals showing on the switchboard.—*I-B-T Instruments, Inc., 141-C Chapel St., New Haven, Conn.*

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STANDARD
All Molded

STANDARD
Brass Barrel
Molded Top

HEAVY DUTY
All Molded
7000 volt Breakdown

Can be furnished in colors—Red, Green and Black
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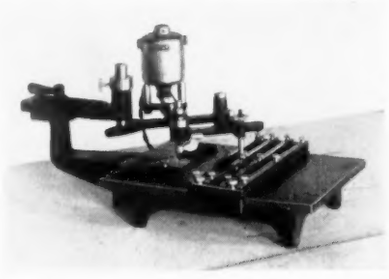
ENGRAVER



For lettering panels of steel, aluminum, brass, or bakelite, or for marking finished apparatus.

Attachments adapt it to small or large work on flat or curved surfaces.

Excellent engraving can be produced by an inexperienced operator.

Widely used for production as well as occasional engraving.

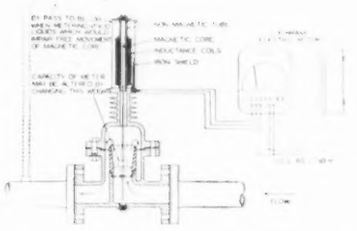
Samples of work and catalogues on request.

Price with Type—$113.50

Mico Instrument Co.
16 ARROW STREET
CAMBRIDGE, MASS.

Area Type Flowmeter

New "Linameter" is adapted particularly to measurement of fluids having characteristics of viscosity, corrosiveness, and solubility (such as fuel oil, ammonia, hot tar, etc.) which are beyond scope of conventional orifice type flowmeter. It is of the area type, with meter body installed as an integral part of the pipe line, and containing a weighted disk whose travel through a tapered throat section is directly proportional to flow rate. Attached to weighted disk is a rod and iron core, the latter of which traverses the field of two reactance coils surrounding pressure-tight tube of meter body. These coils form a reactance bridge when connected electrically to similar coils in the indicating, recording and integrating instrument at any desired distance from the meter body. Measurement is accomplished in the remote instrument by use of the galvanometer null principle, as in maker's Electric Flow Meter (see *Instruments*, Jan. 1935, page 25). Among the features are uniformly graduated indicator and chart scales; means of conveniently changing capacity range; wide range of available capacities; negligible pressure loss; no need of straight pipe runs. Meter is made in different combinations of indicating, recording and integrating features; and may be equipped with pressure and temperature elements to record on the same chart with flow. Styles are available for wall, column or flush panel mounting.—*Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.*



Ring-balance Flowmeter

New model of maker's mechanical meter of the ring-balance type for metering steam, water, gas, air, etc., at static pressures up to 1000 lbs./in.² (see *Instruments*, May 1939, page 132) is announced. New meter will give full scale readings on differentials as low as 3" water; is housed in a steel case suitable for exposed locations; is convertible from one scale-range to another by changing a calibrating weight; has a 12" evenly-graduated chart; is furnished with any combination of indicator, recorder and cyclometer type integrator.—*Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.*

Wheelco
POTENTIO-TROL

This revolutionary control instrument provides ultimate efficiency when applied to your most exacting temperature control problems. The combination of the highly sensitive Wheelco "Radio Principle" electronic control system and the time-proved potentiometric method of temperature measurement has established a degree of instantaneous control action heretofore unknown. Let us demonstrate how your production will benefit by this new control system.

Write for complete information.

Wheelco Instruments Co.
1929-33 S. HALSTED STREET • • • CHICAGO, ILLINOIS

A LABORATORY JOB DONE IN THE FIELD

HAYS PORTABLE COMBUSTION TEST SETS are equipped to handle an accurate gas analysis—right in the field.

Installations become more successful, trouble-makers are rapidly exposed, guesswork becomes a thing of the past.

Test Sets are available with all necessary equipment for the analysis for CO_2, CO, and O_2—complete with flue gas thermometer, and draft gage. For further particulars—write to 925 Eighth Avenue, Michigan City, Indiana.

THE HAYS CORPORATION
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

Battery Testers

(1) New Volt-checker (Fig. 1) has an adjustable prod which furnishes a load equal to the starting load on the battery during a test, without necessity of stepping on starter. Instrument gives the reading while the load is being applied. A rubber lead, permanently attached to a contact in top of the adjustable prod, may be connected to the 3-volt binding post on the Volt-checker. In top of prod is a well into which Volt-checker is inserted. Prod will fit any battery cell. Volt-checker's accuracy is within 2%.

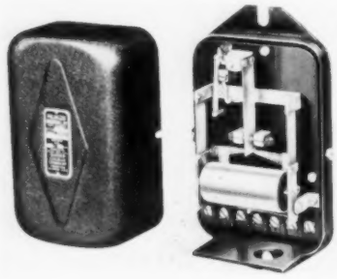
Fig. 1

Fig. 2

(2) New Cell Tester (Fig. 2) has adjustable prods enabling it to fit any battery cell. It replaces at a lower cost a former G-E tester which was not adjustable. It is easy both to hold and adjust. An S-shaped resistance fixed permanently to prods acts as a load supplier and also as a spring for prod adjustment.—*General Electric Co., Schenectady, N. Y.*

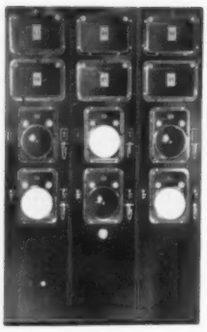
Polarized Relay

New "Polarized Microrelay" is a new balanced type relay which may be used in either a.c. or d.c. circuits. A recommended instrumentation use is in self-balancing



bridge circuits for positioning motor-operated devices from either manually or automatically positioned potentiometers. Another is in the high-temperature instrument field where a proportioning type potentiometer controller is used to position a motor-operated valve. It can also be used as a voltage- or current-sensitive relay, and as a conventional relay to protect delicate contacts in other circuits. Movement of tongue between contacts is governed by four coils contained in the solenoid cylinder. An armature is suspended horizontally in the axial center of this cylinder. When it is affected by a magnetic pull at either end of the cylinder, because of an unbalanced condition in the bridge circuit, this motion is transmitted to the tongue causing it to move to one or other of the contacts. This balanced solenoid action is said to permit rugged construction without affecting the sensitivity.—*Barber-Colman Co., Rockford, Ill.*

FALSTROM



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20 WEST 47th ST., NEW YORK

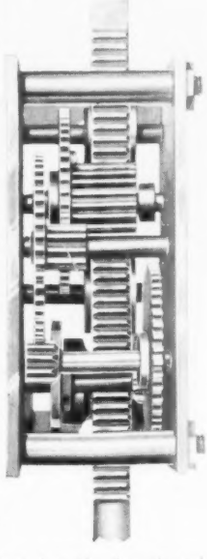
Duplex Recorder

New "Type CD-37" duplex recorder for recording simultaneously kw. and rkva., or kw. and frequency, or volts and amperes, may be had with any two of the elements

formerly available singly in the "Type CD" instruments. It consists essentially of two separate "Type CD" instruments placed side by side in one case and recording on a single chart. Timed by a high-torque Telechron motor, or an 8-day spring clock, the chart carriage feeds the paper at 1", 2", or 3" per hour. Metal pins on each end of timing drum, engaging holes on each side of chart, assure positive drive. Each element, equipped with a conventional pen and ink-well, is calibrated for a 4" ruled section of the 10" chart. Instead of a single wide chart, a separate standard "Type CD" chart carriage and chart may be had for each element. The two recording mechanisms are enclosed in a sheet-steel case for semiflush switchboard mounting. Two lamps, one over each element, provide internal illumination. Connections are made on back of case—*General Electric Co., Schenectady, N. Y.*

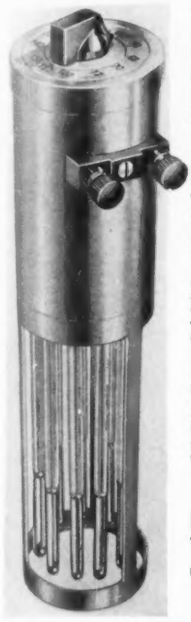
Timing Mechanism

New gear and escapement mechanism for instrumentation devices consists of a train of heavy gears, pinions and a gear rack. When operated by weight or spring, rack drives gear train through a ratchet-held loose pinion which, on reverse motion, is released to permit rack to be manually or electrically returned to its starting position. May be adapted for mechanical tripping or electric control operation in fixed or adjustable intervals and single or repeat operating cycles. Unit is constructed of heavy brass and steel with gears and pinions cut from solid stock. Points of wear are hardened. A variety of timing ranges from a few seconds up to approximately 3 minutes is possible depending upon gearing, length of rack and operating weight utilized. Suitable for production applications on which an adaptable time delay mechanism of mechanical type is required. Available only in quantities on special order.—*Walser Automatic Timer Co., 420 Lexington Ave., New York City.*



Eleven (or any convenient number) Thermoregulators in ONE Assembly

combining—
ACCURACY of Mercury Expansion
RELIABILITY of Single Point
FLEXIBILITY of "Multiple" Idea



Here, at last, is the precision control system to meet the requirements of exacting customers who—up to now—had to choose between the precision (minus flexibility) of one mercurial thermoregulator and the convenience (minus reliability) of a variable-setting instrument.

Ideal for Viscosimeter Baths, etc.

This new Multiple Thermoregulator was developed for viscosimetry. Control setting accuracy 0.1°F.; sensitivity 0.025°F.

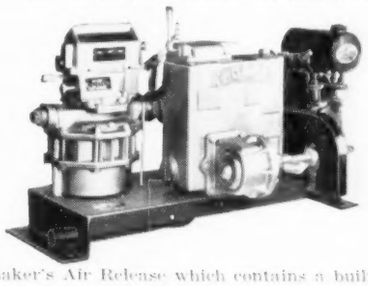
Although the basic idea is simple, its realization now announced represents thorough research, full development, long service tests and many refinements. Every instrument is guaranteed. Cut shows eleven-unit combination 2½" diam. x 11¼" long. Selector switch and temperature settings at top, in plain view. Each unit is easily replaceable, permitting changes in single temperature settings.

Write for Temperature Control Catalogue

PHILADELPHIA THERMOMETER COMPANY
915 FILBERT STREET
PHILADELPHIA, PA.

Self-powered Metering and Pre-set Delivery Outfit

New "Xactopack" is a complete and self-powered assembly of equipment comprising maker's "Xacto Meter," a pumping unit, gasoline engine for operating the pump, and



maker's Air Release which contains a built-in strainer and by-pass relief valve. "Xactopack" can be supplied with any of the maker's standard dials: Vertical, Swivel, Straight Reading with facilities for illumination, Recording Printer, or the regular Horizontal Type Counter. Any of these dials can be used with maker's Pre-determining Adapter for delivering pre-set quantities. Pump is positive-displacement, giving relatively high vacuum. Engine is Lauson "Model RLC," approx. ¾ h-p. Outfit is especially valuable where deliveries are fairly small and frequent. Power-operated pump naturally makes much faster delivery possible by eliminating present practice of bucketing; and it provides greater economy by obviating use of truck motor for operating a power take-off equipped pump. "Xactopack" finds applications around the bulk plant, in factories where small amounts of refined petroleum products are handled, by road contractors for filling tanks of graders, etc.—*S. F. Bowser & Company, Inc., Fort Wayne, Ind.*

WHEELCO SURFACE TEMPERATURE PYROMETER

★

A light weight, precision built, self-contained pyrometer with open faced, easily-read scale for temperature reading of all surfaces (stationary or moving). Commonly used on plastic, paper and textile mill rolls, motors, bearings, etc. Adjustable joint has 180° flexibility, for positioning to convenient working angle.

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Write for Complete information

Wheelco Instruments Co.
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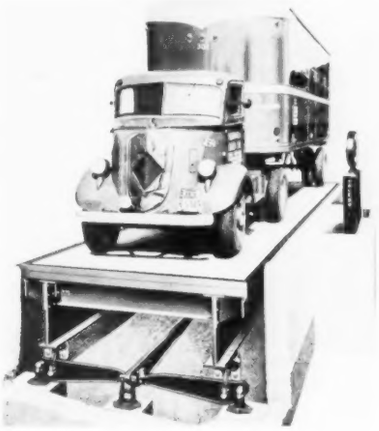

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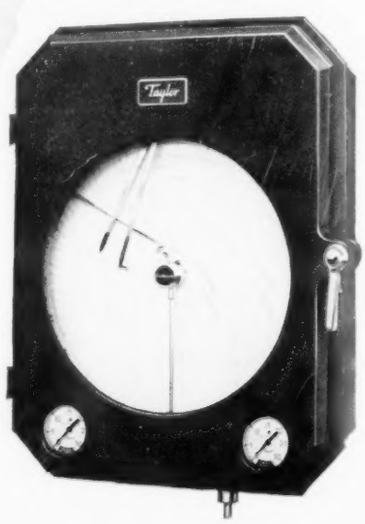

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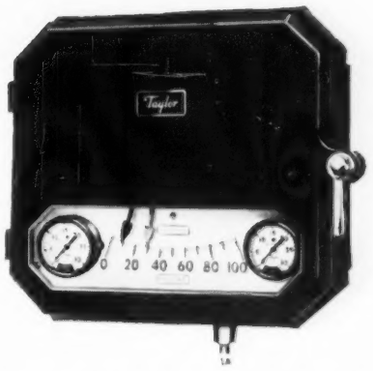

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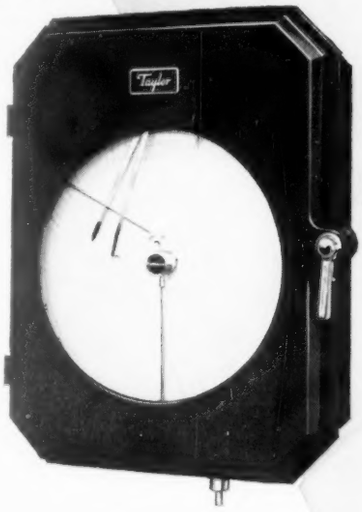

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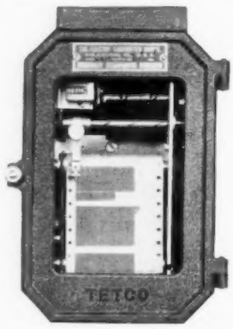

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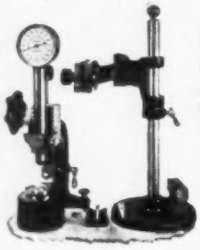

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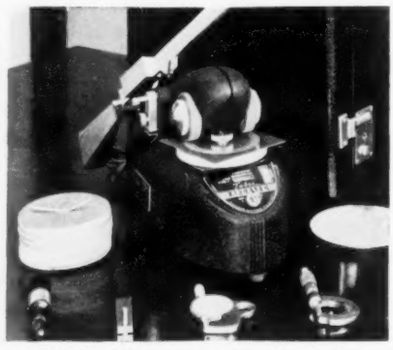

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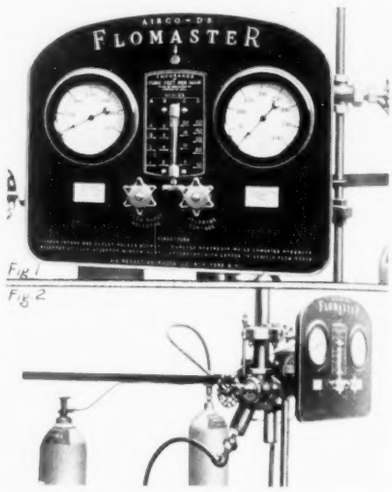

Fig. 1
Fig. 2

mand rate and inlet pressure as storage bank is drained from 2500-lb. down to its terminal value. In order to assist in estimating probable drainage time for particular storage bank, as well as to check economy in utilization of oxygen and possibility of heavy line leaks, controller is fitted with a flow indicator. Although designed specifically for oxygen, controller with minor changes in built-in flow indicator will be suitable for air, nitrogen and hydrogen. A flow-range selector is provided which, by controlling the size of a by-pass orifice, gives the flow indicator four different overlapping flow ranges. Referring to Fig. 1, the particular by-pass being used is indicated by the letter displayed in circular opening directly under arrow shown just above the flow indicator. Delivery pressure of the controller is governed by a pilot regulator, the adjusting hand wheel of which marked "Pressure Control" is in Fig. 1. Pilot regulator discharges gas directly into control dome bolted over diaphragm of main regulator. Capacity of control dome is augmented by means of a reservoir (left-hand cylinder, Fig. 2) to make delivery pressure substantially independent of variations in diaphragm position, and therefore in demand rate. Main regulator body is fitted with a ½" relief valve. A 3" bursting disk provides additional safety. A large-area glass-wool filter, just upstream from regulator nozzle, enhances dependability. Purpose of right-hand cylinder (Fig. 2) is as follows: When 2500-lb. pressures are suddenly admitted into a reducing valve, gas initially in passages is compressed so that exceedingly high temperatures may develop. Because high temperatures in vicinity of valve seat and in presence of oxygen are undesirable, the dead-end chamber is provided, into which the hot gas is pushed while the cold gas flowing from the storage bank is brought in contact with the seat. (Principles involved discussed in article by G. M. Deming, *Instruments*, Sept. 1933, pages 167-170.)—*Air Reduction Sales Co., 60 E. 42nd St., New York City.*

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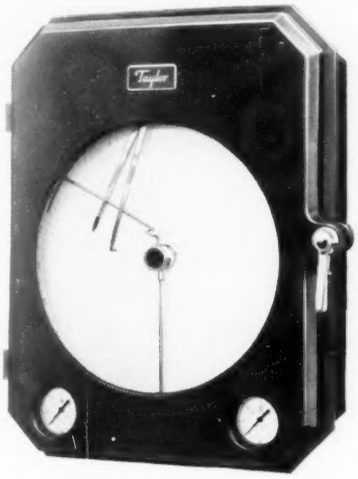
completely redesigned line of "Ful-" air-operated recording and indicating ollers for temperature, pressure, rate-w, and liquid level, is announced. In tion to the convenience of combining in instrument the conventional propor-l-response and automatic-reset modes ontrol, new Fulscope introduces a third "Pre-Act," which makes control-valve rections according to the rate of control-deviation. Over-peaking or oscillating reduced by an immediate and relatively



larger control-valve action than would occur otherwise. Operation is stabilized after a change in set point, or when equipment is started up. Automatic-reset feature, which compensates for changes in load, is fully adjustable over a much wider range than previously. So is continuous controller sensitivity (throttling range) which provides adaptability to process time lag. Inherent compensation for fluctuations in air-supply pressure makes relation between pen movement and output air pressure change so linear that instrument may be used for a remote pneumatic transmitter. Ease in making adjustments in sensitivity, automatic reset rate, and Pre-Act time is enhanced by magnified dials, calibrated in absolute units. Recorder-controllers are available with two complete control mechanisms with any combination of primary systems except two manometers. Interchangeable unit construction permits field conversion from one form to another. Temperature and pressure systems are easier to replace in the field with factory-calibrated ones. Simplified air system includes improved relay air valve with precisely drilled sapphire orifice; removable 18-8 stainless steel nozzle; inbuilt metal-disk auxiliary air filters supplement large external filter. Other improvements include new, more durable electric chart clock which also is available in explosion-proof housing; spring-driven clock optional; improved rapid chart changing mechanism; Neoprene gaskets throughout. Available in five standard types: Fixed high sensitivity; adjustable sensitivity; adjustable sensitivity with automatic reset; adjustable sensitivity with "Pre-Act"; and adjustable sensitivity with automatic reset and "Pre-Act."—*Taylor Instrument Companies, Rochester, N. Y.*

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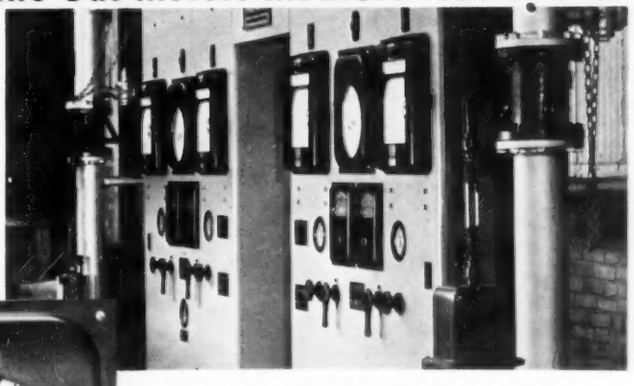

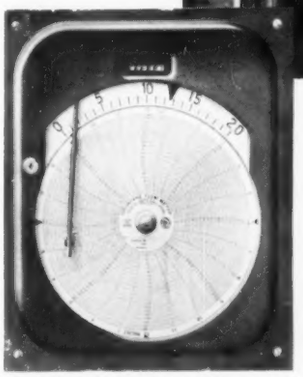

AT Carnegie-Illinois Steel Corporation's Edgar Thomson Works, 16 Cochrane Electric Flow Meters help to maintain uniformity of steel by measuring the flow of gas to soaking pits in terms of Btu. automatically compensating the volumetric rate of flow for changes in Btu content. An additional Cochrane Meter is used as a master Btu recorder.

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Selecting Automatic-control Equipment for Continuous Processes

By H. H. GORRIE
Control Engineer, Bailey Meter Co., Cleveland, Ohio

IN many cases automatic control is a requisite for the satisfactory operation of continuous processes. Failure to obtain satisfactory or improved operation through the application of control equipment to a given process can result from (1) mechanical or electrical failure of the control equipment, and (2) incorrect application to the process.

In regard to (1), it may be safely said that practically all control manufacturers' equipment is mechanically and electrically sound and will perform creditably if correctly applied. It follows that the control equipment will stand or fall according to its correctness of application to the process. In general, the specification as to the type of equipment required for satisfactory control is left to the control manufacturer, but the user will be in a better position to make the final selection if he has a good grasp of the fundamental considerations involved.

(EDITOR'S NOTE—"The number of classes, types and varieties of process control devices on the market is growing so fast that we need a brief, easily-understood guide to take us through the maze of literature. And spare us the mathematics!" Such was the gist of recent requests. . . . Almost in the same mail, there came Mr. Gorrie's article!—MFB)

Broadly speaking, the correct application of control is dependent upon such factors as the arrangement, type and design of process equipment, the accuracy required, and the type and character of load changes.

It obviously would be extremely difficult, if not impossible, to tabulate the correct application of each manufacturer's equipment to each different process. Even if such a list were compiled, it would be an endless task to keep pace with new processes, process equipment changes, and changes in manufacturer's equipment. It is, however, possible to classify the different types of more commonly used control mechanisms, as well as the more important fundamental process characteristics, on which knowledge the application of control equipment to a process may be studied.

THE BASIC ELEMENTS OF A CONTROL SYSTEM

Fig. 1 illustrates the application of control to an oil heater to maintain the oil temperature leaving the heater within definite limits. Steam to the heater is the control agent, the rate-of-flow of which is adjusted by means of a control valve. The temperature is measured by means of a gas-filled bulb located in the oil line from the heater, which actuates an indicator-controller of the relay type, to establish loading pressures proportional to temperature variations. The loading pressure from the controller commands a power unit to open or close the control valve.

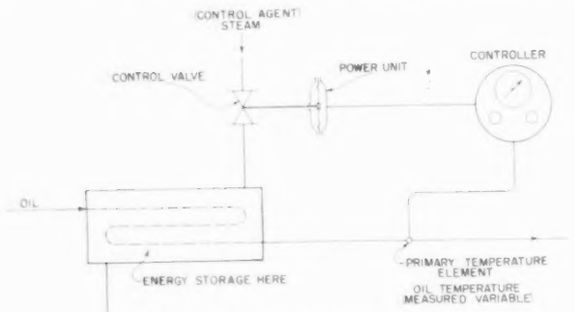


Fig. 1. Basic Elements of a Control System.

CLASSIFICATION OF CONTROLLERS

The operating characteristics of a control system are determined by the controller design.

The more common types of controllers may be classified as follows:

1. On-off
2. Floating
3. Positioning
4. Positioning and Floating

On-off Control

On-off Control consists of a pneumatic device or electrical contacts to quickly operate the control valve from open to shut for relatively small deviations in the measured variable. It is important that the contacts or the pneumatic device be adjusted to reverse the position of the valve on changes in the measured variable of less than 1%.

This type of control results in a continuous cycle in the measured variable and also in extreme variations of the control agent. In certain processes these cycles are of relatively no importance, but in other processes they are extremely undesirable. This latter statement is particularly true when control is applied to a part of a process where these cycles may extend through or aggravate the remainder of the process.

This type of control is only applicable to certain processes having large energy storage, such as electric furnaces, air compressors with large receivers, etc.

Floating Control

In floating control the controller is arranged to operate the control valve continuously in one direction or the other, for relatively small deviations in the measured variable. This valve motion is relatively slow and it therefore does not reach its extreme open or shut positions in normal operation. The valve action may be at a constant rate or variable rate, depending upon the controller design.

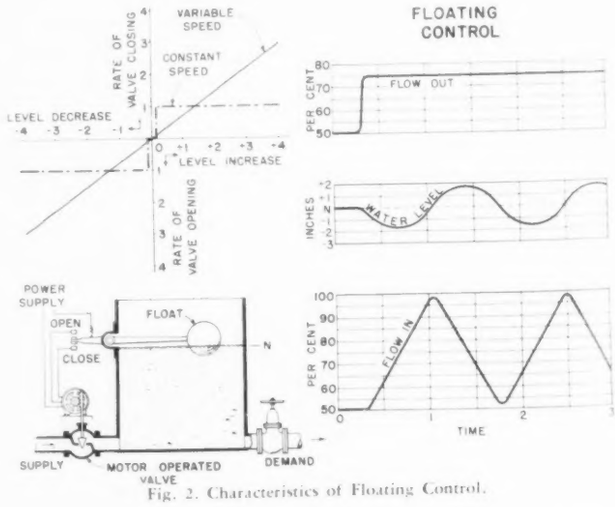


Fig. 2. Characteristics of Floating Control.

The characteristics and performance of floating control are diagrammatically illustrated by Fig. 2.

In comparison with on-off control a floating control, when applied to processes having large energy storage, may be adjusted to eliminate the violent surges characteristic of the on-off control. However, under these conditions, the valve motion must be relatively slow and the control will be ex-

...ly unsuited for rapid or wide fluctuations in load. On ...other hand, variable-speed floating control will result ...highly satisfactory control when applied to processes ...ing extremely small energy storage.

...itioning Control

...n positioning control the control valve position is pro...tional to and corresponds with the measured variable ...thin the positioning range. The valve is closed at the one ...de of the range and open at the other. As the load on the ...stem varies the regulating valve position must be changed, ...nd the consequence is that the measured variable changes ...proportion to the load change. The change is measured ...riable for full valve motion is generally adjustable over ...wide limits.

The characteristics and performance of positioning control are diagrammatically illustrated by Fig. 3.

An inherent characteristic of this type of control is that it can be adjusted to be absolutely stable. When two or more controllers are operating on the same system, this characteristic of positioning control is desirable and often necessary to prevent inter-action between controllers.

The disadvantage of positioning control is the change in measured variable with load changes. This is known as the positioning range. In processes having large energy storage the positioning range is small and generally can be tolerated, but with processes having small energy storage, the positioning range must be larger and in some cases becomes detrimental to satisfactory operation.

Positioning and Floating Control

In Positioning and Floating Control the primary action is that of a positioning control and therefore this system has the operating stability characteristic of positioning control. The secondary action is that of a floating control and this element eliminates the undesirable characteristic of positioning control, namely the change in the measured variable with changes in load. The floating element of the control is adjusted to slowly superimpose its control on the positioning control to reset the measured variable to its desired value. This type of controller is required whenever a positioning type of control is required for stability, but where operating conditions are such that a wide variation of the measured variable cannot be tolerated.

TYPICAL CONT...OL PROBLEMS

TEMPERATURE CONTROL

Any problem in temperature control is that of balancing heat supply to heat demand in a given process. Considering any heat exchanger, the following are some of the fundamental factors involved in temperature control:

1. Heat Energy Storage
2. Transfer Lag
3. Transportation Lag
4. Controller Lag

The first three factors may be grouped under the general heading "Application lag," since they are a function of the design and arrangement of the controlled apparatus.

The fourth factor, "Controller Lag," is a composite term combining all of the individual lags existing in the controller and its related equipment, i.e., regulating valve, manual selector unit, etc.

The importance of these factors on the problem of temperature control are briefly as follows:

1. Heat Energy Storage.

Normally, the quantity of heat in a heat exchanger is considerable, as compared to the steady rate of heat supply and, therefore, this heat storage is an important consideration in the control problem.

The effect of energy storage on the system during momentary fluctuations in temperature is determined by the amount of stored heat released and absorbed on a unit change in temperature as compared with the steady rate of heat supply.

This energy storage may be divided into two parts: (1) demand side energy storage and (2) supply side energy storage.

When the demand side energy storage is large and the supply side small, the process is favorable for precise control. This is true because the small quantity of heat available from the supply side of the heat exchanger, as compared with the large quantity of heat on the demand side, means that on a change in the flow on the supply side, there is a relatively small heat storage to cause over-shooting, with the result that the temperature on the demand

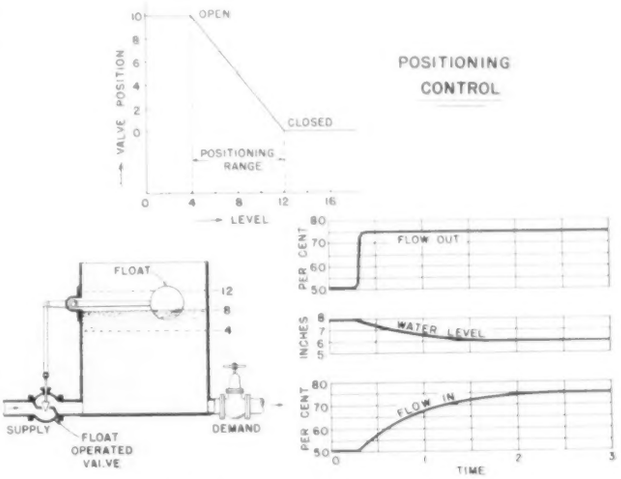


Fig. 3. Characteristics of Positioning Control.

side will change relatively slowly. This accounts for the fact that on-off control is satisfactory on electrical heating furnaces or domestic gas heating furnaces. Naturally, this same condition improves the operation of floating control and will require a smaller positioning range on the positioning control.

If the supply and demand energy storage conditions are reversed the opposite result is true. This condition is exemplified by the coal-fired domestic furnace. Here the supply side energy storage greatly exceeds the demand side energy storage, and it is difficult to prevent over-shooting.

2. Transfer Lag.

The thermal resistance between the two parts of a heat exchanger prevents the free flow of heat from the supply side to the demand side. This lag is a function of the exchanger design, transfer media, and velocities within the exchanger.

Under steady operating conditions, a constant temperature difference exists between the supply and demand sides. As the load on the heat exchanger is increased, the temperature drop across the transfer surface increases and requires that the temperature head on the supply side be increased to overcome the resistance. This causes a delay in the response on the demand side to a change on the supply side and tends to cause over-shooting with any type of control system.

3. Transportation Lag.

Transportation lag may be defined as the time required for a change in temperature in the exchanger to reach the point where the sensitive bulb may be located. This may not be serious at high loads, but becomes increasingly more important at the lower loads.

The result of this lag is again to delay the response of the controller to a change which has already existed in the heat exchanger, with the result that the valves are held in the open or closed position over too long a period.

4. Controller Lag.

In a temperature controller, the controller lag consists of the following individual lags:

a. Primary element (i.e., bulb or thermocouple) transfer lag.
b. Measuring element lag or error
c. Controller transmission lag
d. Power device or valve positioning lag or error.

In temperature control the only item of importance is item (a) which must be held to a minimum through proper bulb design and installation. The controller lag is negligible compared to the application lag in properly designed controllers and related equipment.

From the foregoing, it can be seen that the factors favorable to precise temperature control, as indicated by smaller cycles in on-off control, and floating control, or a smaller positioning range with positioning control, are as follows:

1. Small supply side energy storage.
2. Large demand side energy storage.
3. Small transfer lag.
4. Small transportation lag.
5. Small controller lag.

Where these conditions are satisfied, any of the controllers described may be used, with, of course, varying results.

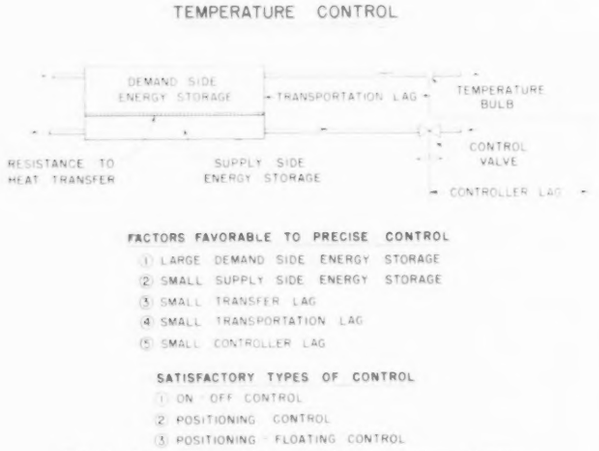


Fig. 4. Factors Favorable to Precise Temperature Control.

The on-off control will maintain the temperature within relatively close limits but, of course, cycling of the temperature and extreme variations in the control agent will be bound to occur.

Floating control will give somewhat more satisfactory control on steady loads but will be so slow as to be of little in the event of a large load change, or in the case of rapidly fluctuating loads.

Positioning control will be quite satisfactory and can be adjusted for a narrow positioning range.

Positioning and floating control may be used where accurate-fast control is required.

Where the supply side energy storage is large compared with the demand side, on-off control will likely cause severe temperature cycles and will not be satisfactory. Likewise, floating control must be adjusted to be slower and will be of even less value with load variations.

Positioning control will require a wider positioning range for satisfactory control and probably a positioning and floating control will be required for satisfactory operation.

The factors entering into the problem of temperature control as well as the factors favorable to precise control, and the satisfactory types of control, are diagrammatically summarized in Fig. 4.

PRESSURE & LEVEL CONTROL

1. Energy Storage

In comparison to temperature problems the energy storage in level and pressure control problems is proportional to the volume of the demand side of the process. The effect of this energy storage is determined by the amount of flow released or absorbed in a unit change in level or pressure as compared with the steady input flow.

Energy storage, therefore, has the effect of retarding the response of the level or pressure to a change in flow to and from the system.

For example, in a large volume supplied by a small control valve, the pressure or level would respond slowly to changes in control valve position, whereas in a relatively small volume with a relatively large control valve the pressure or level would respond rapidly to changes in control valve position.

Pressure or level control problems having considerable energy storage are, therefore, easier to control than processes having small energy storage because under these conditions the pressure or level is less sensitive to changes in either the supply or demand.

2. Controller Lag.

Pressure and level problems having extremely small energy storage require that the controller lag be taken into consideration. As described in detail under Temperature Control, every control system has a certain amount of lag or delay in its response to changes in the pressure or level. In other words, a definite time elapses from the time the pressure or level changes until the control valve is moved by the control system.

The smaller the amount of energy storage the faster the level or pressure changes in comparison to the fixed time for the control system and the more difficult the control problem becomes.

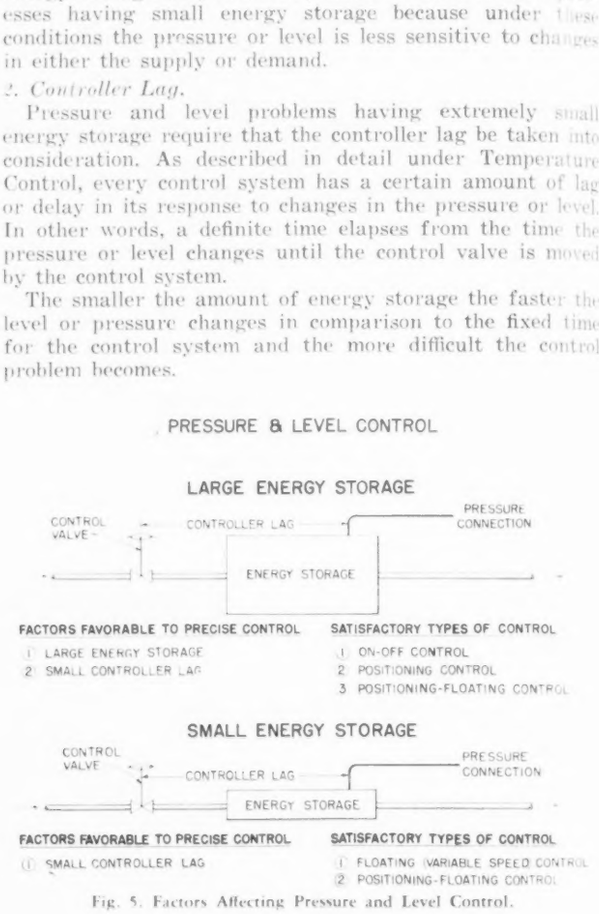


Fig. 5. Factors Affecting Pressure and Level Control.

From the foregoing it can be seen that the factors favorable to precise draft or level control are

1. Large energy storage
2. Small controller lag

Where a large energy storage exists, any of the abovementioned types of control may be used with, of course, varying results. The on-off control will be able to maintain the pressure or level within relatively close limits but cycling of the pressure or level will occur. An example of such control is start-stop or centrifugal unloading control on an air compressor.

Floating control will give somewhat more satisfactory control with steady loads, but it will be so slow as to be of no value in case of rapidly varying loads.

Positioning control will be quite satisfactory for this type of installation and may be adjusted for a narrow positioning range. An example of such control is a reducing valve.

On installations where accurate and fast regulation is required, positioning and floating control should be used.

With a relatively small amount of energy storage, conditions are somewhat changed.

The on-off control will not be satisfactory because there is not sufficient energy storage to absorb the rapid fluctuations in supply.

The floating control, on the other hand, may be quite satisfactory. The constant speed type will afford fair control and the variable speed type will be capable of close control and at the same time may be adjustable for lively action.

Positioning control may be satisfactory if the positioning range can be made large enough, but generally it is necessary to resort to the positioning and floating control for satisfactory control. *(Continued on Page 109)*

PRESENT STATUS OF INSTRUMENTS FOR
Measuring Riding Comfort

By ROY W. BROWN

Automotive Research Division, Firestone Tire & Rubber Co., Akron, Ohio
Chairman, Riding Comfort Research Committee, Society of Automotive Engineers

RIDING COMFORT instruments may be divided into three broad groups: (1) Instruments capable of actually measuring any, or some, or all, of the various rhythmic or non-rhythmic vibrations or other movements of the motor car which cause discomfort and fatigue to the passengers. (2) Instruments more or less of a research nature, used in the suspension laboratory to measure the performance of the motor car suspension and its various related functions. (3) Instruments designed to measure the mental and physical effects of various vibrations on the passengers. This article summarizes the present status of Group 1 instruments. It incorporates the full text of the mimeographed report presented to the S.A.E. Riding Comfort Research committee with the Instrument Exhibit at the 1938 Summer Meeting of the S.A.E. It brings the report to date (April 1940). By special arrangement made with the Editors of the *S.A.E. Journal* and of *Instruments* it is published in the latter magazine and made available to all interested workers.

INSTRUMENT REQUIREMENTS

During the past seventeen years there has been a growing trend toward substituting quantitative measurements for personal observations in evaluating riding comfort. At first, however, the "trend" was a mere "wish"—which could not be fulfilled because no one knew just what to measure and how to measure it. Early work, therefore, consisted largely in (*a*) discovering measurable factors, (*b*) classifying these factors with regard to their bearing upon "comfort" and (*c*) painstakingly formulating the specifications of appropriate measuring instruments. Each of these three phases of the work affected the other two. Thus the appearance of the first specific-function instruments resulted in improving (*a*) and (*b*) and in revising (*c*), thereby leading to the design of still more suitable and more accurate instruments, and so on. Gradually, the art became a science and various lines of investigation were coördinated. A "milestone" in formulation was promulgated five years ago: In an effort to make their work more generally available, the Riding Comfort Research Committee then summarized ten instrument requirements essential to accurate performance.[1, 2]

It is important that the instrument be capable of measuring accurately motor car vibrations in terms of fundamental measurable factors. The more important factors are *time*, *displacement*, *velocity*, *acceleration* and possibly rate of change of acceleration. In Fig. 1, the relationship of displacement, acceleration and the time a given acceleration is exceeded for harmonic motion are outlined and some fundamental formulae given. This figure also illustrates the action of a contact type accelerometer whose mass is suspended magnetically midway between an upper and lower contact.

Adequate damping of the moving element in the instrument is necessary for accurate results. This is especially important in instruments having a moving system with a natural frequency of three times or less than the frequency of the vibrations being measured.

Dynamic calibration at amplitudes and frequencies covering the range in which the instrument is to be used is necessary to validate the accuracy and usefulness of any instrument used under the complex vibration condition occurring in a motor car.

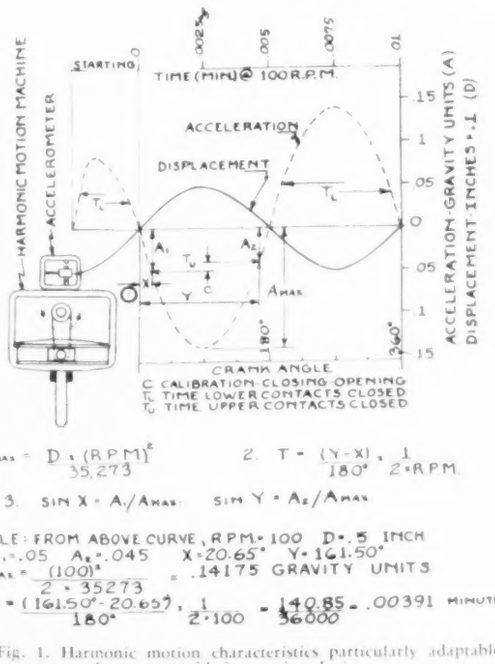
Simple harmonic motion has been adapted to dynamic calibration of vibration instruments.[3] The systematic deflection of metallic springs may be utilized.[4] An ingenious method used in Germany[5] is to mount the accelerometer on the axis of a rotating shaft so that the axis of the accelerometer may be varied in reference to the shaft axis.

INTEGRATING ACCELEROMETERS

Since the description in 1926 of the contact accelerometer[6] several attempts have been made to simplify the original recording and counting instruments used to determine the contact action in the accelerometer when it was subjected to an acceleration greater than the value to which its spring mass system was adjusted.

In the Chrysler instrument, Fig. 2, this is accomplished by means of starting and stopping an electric timer for each operation of the accelerometer contacts. This type in-

For numbered references see Bibliography on page 106.



1. $A_{MAX} = \frac{D \times (R.P.M.)^2}{35,273}$ 2. $T = \frac{(Y-X)}{180^\circ} \times \frac{1}{2 \times R.P.M.}$

3. $\sin X = A_1/A_{MAX}$ $\sin Y = A_2/A_{MAX}$

EXAMPLE: FROM ABOVE CURVE, R.P.M. = 100 D = .5 INCH
$A_1 = .05$ $A_2 = .045$ $X = 20.65^\circ$ $Y = 161.50^\circ$

(1) $A_{MAX} = \frac{(100)^2}{2 \times 35273} = .14175$ GRAVITY UNITS

(2) $T = \frac{(161.50^\circ - 20.65^\circ)}{180^\circ} \times \frac{1}{2 \times 100} = \frac{140.85}{36000} = .00391$ MINUTES

Fig. 1. Harmonic motion characteristics particularly adaptable to contact accelerometers with integrating devices.

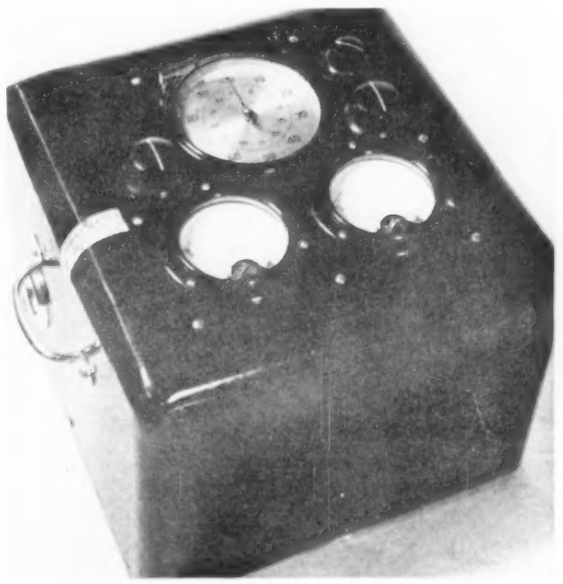


Fig. 2. Chrysler Electric Timer Integrating Accelerometer.

strument is subject of course to the ability of the clock to start and stop during the comparatively short time interval accelerations occur.[1]

To overcome this limitation, Firestone adapted an induction watthour meter[1] to integrate the time pulses as determined by the opening and closing of the accelerometer contacts. It was found that the friction required to start the induction meter interfered with accuracy in integrating short time intervals. An electronic integrator, Fig. 3, has now been developed which has completely overcome this difficulty. This instrument is self-contained, operates off the car battery and can be calibrated directly with a stop watch. A typical element is shown on the inside of the cover at the right. Permanent magnets have been substituted for the solenoids previously used. Adequate damping to prevent contact chatter is secured by eddy current methods. Elements can be located on the axle, frame, floor boards, or seat cushions and the instrument adjusted to integrate the total with any relative evaluation desired.

A recent development in England has made commercially available an integrating accelerometer, Fig. 4, using the induction meter principle.[2] The makers advise that the instrument is available for a range from 8 ft./sec./sec. to 160 ft./sec./sec. and accurate to within 2% on any acceleration of 20 milliseconds or longer. The accelerometer element weight $4\frac{3}{4}$ lbs., is of the electromagnet contact type. Acceleration of the unit causes control of a portion of the current fed to the induction meter from a motor-alternator operating from a 12-volt 9-amp. battery supply.

The integrating or counting type of Riding Comfort measuring instrument is necessary if data under service conditions are to be quickly and conveniently obtained. Either type may be used to totalize the several hundreds of accelerations which occur each mile (Fig. 5) or the many millions which occur on a trip say from Chicago to New York. The completion of the development of this type of instrument now provides means of correlating Dr. Moss' work on human fatigue[10] with vibration as it exists in motor cars under actual road service conditions.

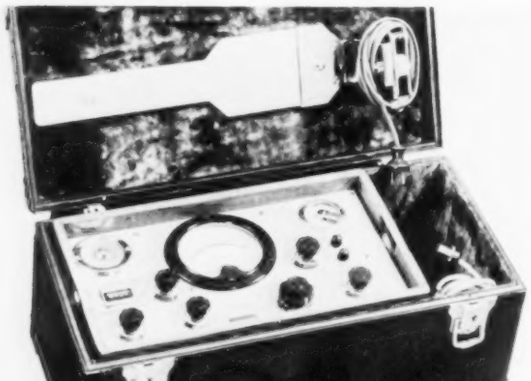


Fig. 3. Firestone Electronic Integrating Accelerometer.

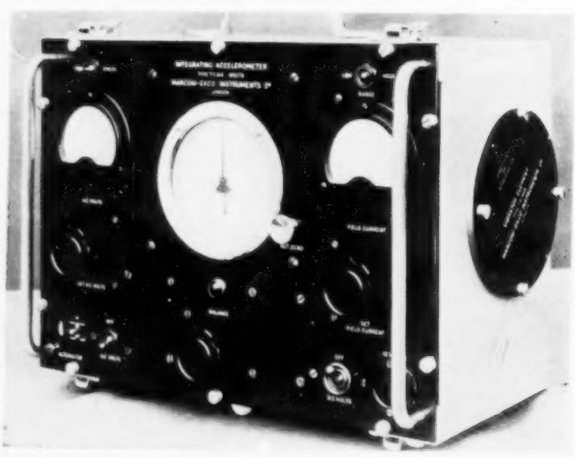


Fig. 4. Marconi-Ekco Induction Integrating Accelerometer.

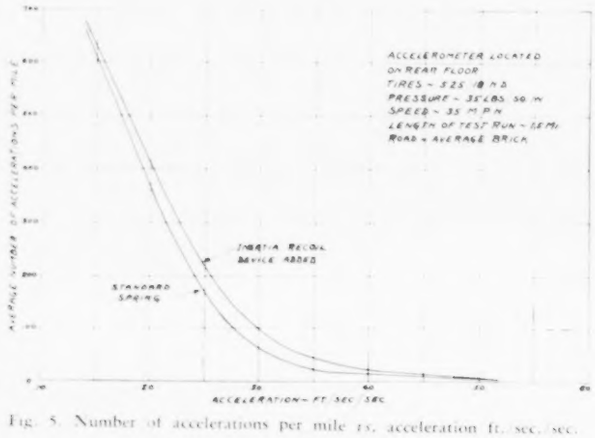

ACCELEROMETER LOCATED
ON REAR FLOOR
TIRES - 525 10 N.D.
PRESSURE - 35 LBS. SQ. IN.
SPEED - 35 M.P.H.
LENGTH OF TEST RUN - 15 MI.
ROAD - AVERAGE BRICK
STANDARD SPRING
ACCELERATION - FT. SEC./SEC.

Fig. 5. Number of accelerations per mile *vs.* acceleration ft./sec./sec.

VIBRATION COUNTING INSTRUMENTS

A pedometer usually consists (Fig. 6) of a weight pivoted on a lever and suspended with a spiral spring. Multiple-leaf springs engage a serrated wheel and function as ratchet pawls to rotate the wheel and pointer gear train when the weight oscillates. No damping or provision for spring calibration is provided. A full indication occurs when the instrument is subjected to a displacement (approximately 0.25") greater than the weight movement and of sufficient acceleration to operate the mechanism. Erratic operation of the ratchet mechanism, partial movement of the weight, in-

Fig. 6 (left). Pedometer (Back cover removed). Fig. 7 (right). Jaquet Vibration Counter (Cover removed to show suspended weight).

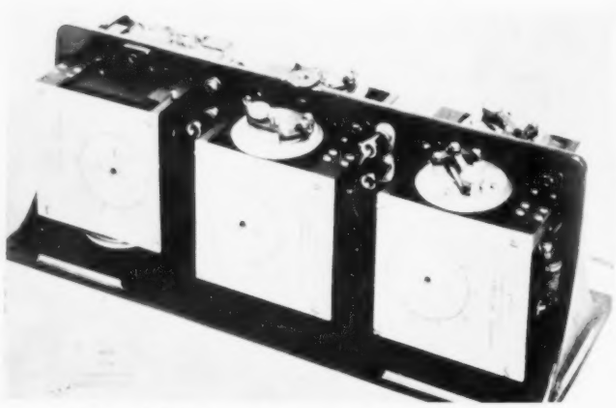


Fig. 8. Cambridge Statistical (mechanical counting) Accelerometer.

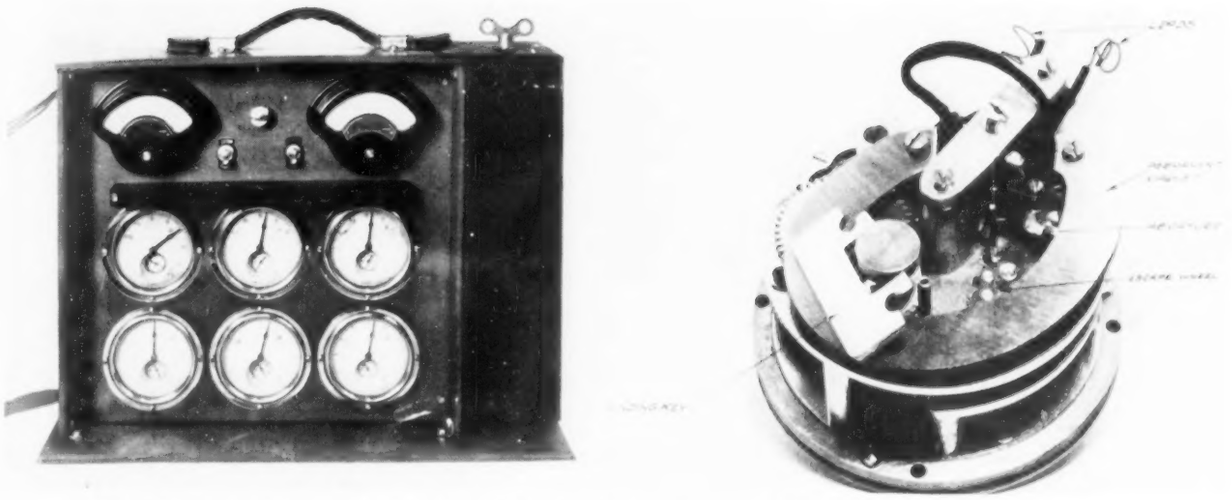


Fig. 9. Firestone high-sensitivity, high-speed, multiple-element Electric Counter. (Back view of one counter is shown at right.)

ability to segregate displacement from acceleration and absence of definite calibration render the instrument unfit for other than preliminary work.

The simplicity of the pedometer has been incorporated in the Swiss instrument,[11] Fig. 7, designed to count the vibrations of suspended cables and claimed to operate on 0.027″ displacement at frequencies above four per second. Provision is made for damping, a substantial calibrated spring is used and the ratchet mechanism is arranged to register one and only one full count for each complete movement of the weight. Otherwise this instrument is subject to the same limitations as pedometers.

Use of the above-described simple instruments has proven the desirability of counting vibrations having an intensity above some predetermined value. In 1928 a high-sensitivity precision counter,[12] Fig. 9, was developed to count accelerations as determined by contact type accelerometer elements. The difference in precision as compared to mechanical counting type may be visualized by comparison of travel of the suspended weight systems of both instruments. The contact accelerometer weight moves only 0.003″ while a pedometer requires around 0.25″ movement and the vibration counter around 0.027″, to insure consistent operation.

ELECTRIC RECORDING ACCELEROMETERS

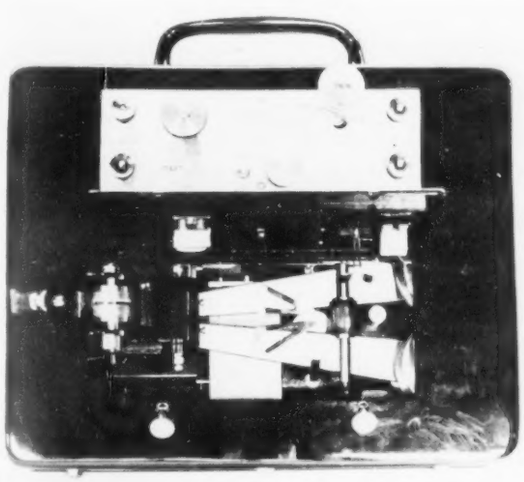
High natural frequency of the suspended instrument system and adequate damping are necessary for accuracy in a curve drawing accelerometer. Such an instrument[13] using the variation of resistance with change in load of a stack of carbon plates was developed and described in 1925. Instruments of this type are now commercially available from at least two sources.[5,14]

Disadvantages are high cost of the recording oscillograph and change of calibration of the carbon stacks. Advantages are flexibility of mounting the elements remote from the recorder and convenience in making simultaneous records from a number of elements at different locations or simultaneous records in all three planes at one or more locations.

CURVE-DRAWING RECORDING ACCELEROMETERS

Need for adequate damping and high natural frequency has presented formidable obstacles in the path of developing an instrument suitable for accurately recording the acceleration time curve of motor car vibrations. A number of instruments are now available suitable for the purpose if used within the range of characteristics for which they are designed. The time and labor required to measure the record restricts the application of the curve-drawing instrument to short tests or to research purposes.

Accelerometers recording by making a microscopic indentation on celluloid with one element and with two elements arranged to simultaneously record acceleration in two planes at 90° to each other are available.[5] The record is magnified optically after removal from the instrument. The two-element instrument is shown in Fig. 10. A typical record of motor car vertical vibration is shown in Fig. 11. With springs giving a sensitivity of 1 mm. deflection for 32 ft./sec./sec. (may be magnified 100 optically) the natural frequency is 40 cycles per second. Ample eddy current damping is provided.



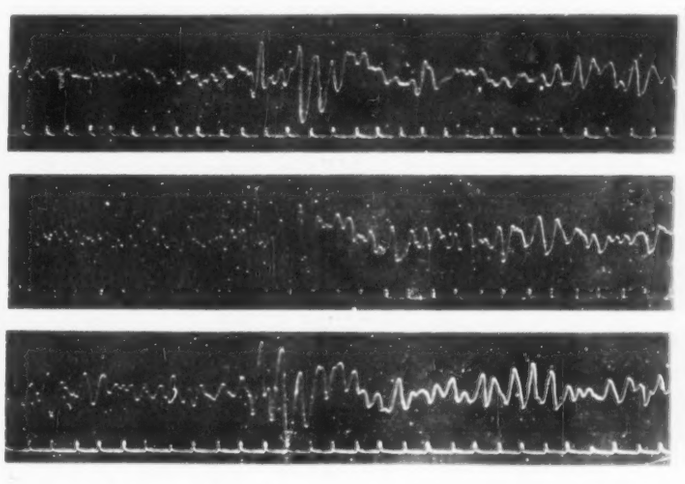


Fig. 10. Cambridge two-element curve-drawing Accelerometer. Fig. 11. Typical record of motor car vertical accelerations.

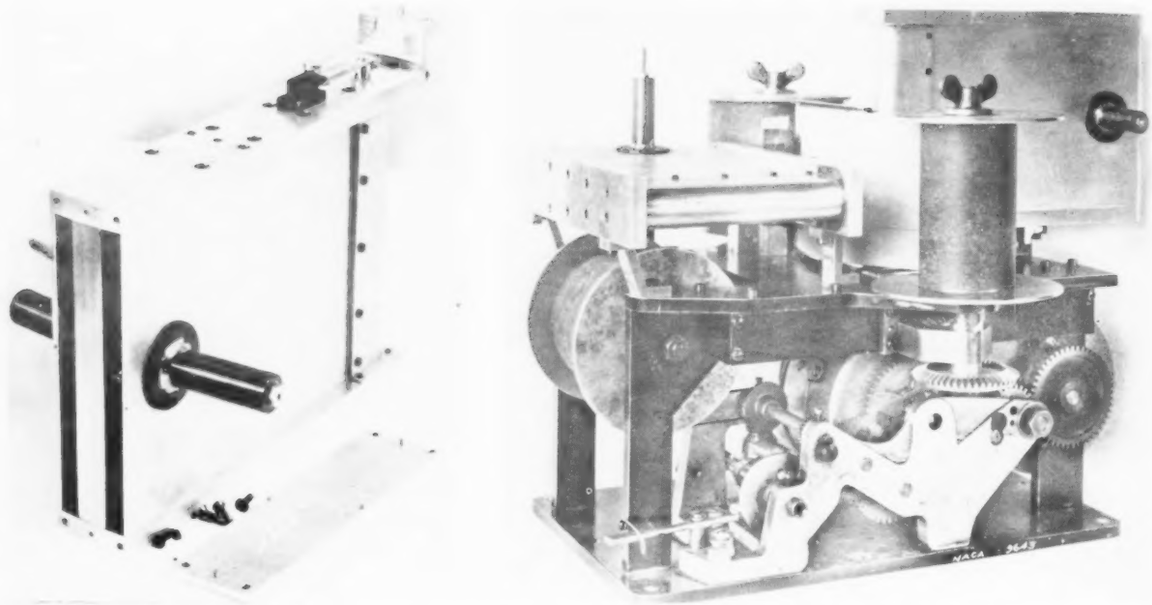
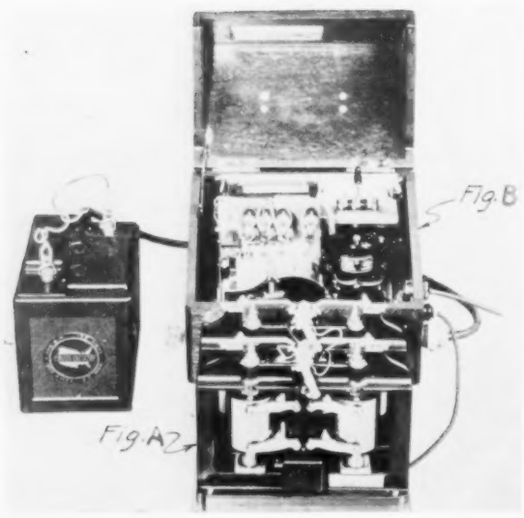


Fig. 12. The N.A.C.A. Recording Accelerometer. Left—Individual unit. Right—Two-component instrument.



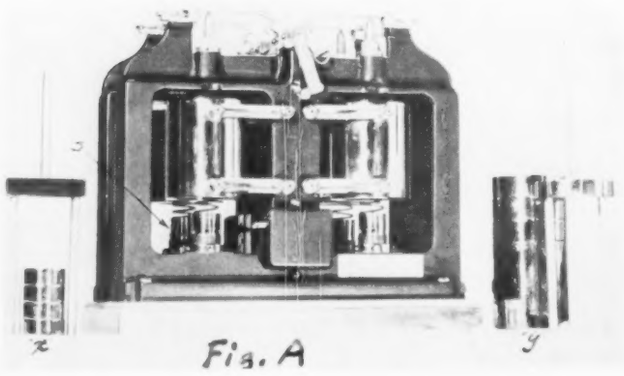
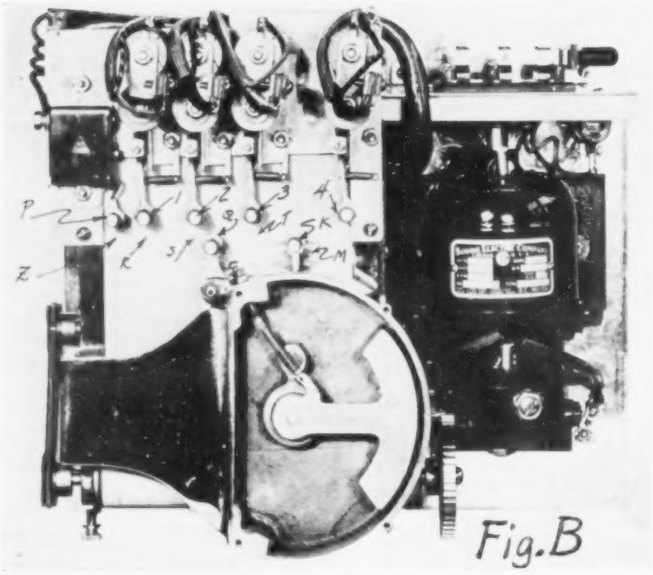


Fig. 13. The Miner instrument for measuring riding qualities of railway freight and passenger cars; and close-ups of weight unit (A) and of recording element (B). This is a special research instrument, not commercially available.



For some years the National Advisory Committee for Aeronautics has used an optical recording-on-film accelerometer[28] for determining maximum forces in airplanes incident to landing and landing gear tests. This instrument, Fig 12, has been redesigned[29] so that it now has a natural frequency of between 12 to 18 cycles per second. The instrument is small and compact and would be useful for recording accelerations such as occur on the seat cushions of motor vehicles.

An interesting instrument of composite type has been developed[31] to record the riding qualities of railways, freight and passenger cars. Fig. 13 shows the set-up which consists of two separate units: a weight unit *(A)* which picks up the vertical floor reactions and a recorder *(B)* which electrically records the action of the weights and also traces the motion of pendulums which act in response to the sway of the car. The weight unit *(A)* consists of four 5-lb. weights mounted in an aluminum frame and guided so that the weights are free to move vertically. Each weight is supported by a spring adjusted to press the weight against a top stop with an electrical contact for a bottom stop. When the instrument is accelerated the contact actuates an electromagnetic stylus. In the recording device *(B)* signal stylus *P* is used to mark the position of mileposts, stations, etc. on the waxed recording paper. Pendulum *K* responds to vertical movement of the car and

pendulum *Q* records the lateral motion, both making marks on the same record with the accelerometer actuated styluses. A small compact optical recording on photographic film accelerometer is now available,[15] with elements arranged to record in three planes mutually at right angles and is illustrated in Fig. 14. Air damping appears to have been carefully worked out. Natural frequency is sufficient for accurate measurement of accelerations that occur on seat cushions of passenger vehicles. A somewhat similar instrument[16] using oil damping was developed sometime ago for special investigation purposes.

An interesting three-component instrument of foreign make[8] has adjustable mechanical and optical magnification ranging from 125 to 3000. Adjustable oil damping is also provided so that aperiodicity may be obtained if desired. A separate photographic film holder and long optical lever make the instrument cumbersome for automotive use.

RECORDING VIBROGRAPHS

Instruments intended to record vibrations having natural frequencies near the frequency to be measured have been extensively developed. While these instruments are not ideal from the point of view of measuring the vibrations in terms of known physical constants, their comparative simplicity, ruggedness and ability to make a direct record without the delay and inconvenience of handling and developing photographic film, makes them well adapted to use on automotive vehicles. Careful determination and attention to the natural frequencies, and the use of stops, appreciably minimize inherent disadvantages. These instruments are called vibrographs to segregate them from true accelerometers.

A typical instrument of the vibrograph type is illustrated in Fig. 15. It is arranged to make simultaneous records of two vibration components at 90° to each other. Air damping is provided. A commercially available instrument[17] using wax paper to make simultaneous record of vibrations occurring in three planes, at right angles to one another, uses stops to limit the record to one half wave, thereby defeating the natural frequency effect of the instrument's spring mass system. Calibration data applicable to instruments with stops has been worked out by The Bureau of Public Roads[18] on their impact accelerometer developed some years ago to measure impact occurring between vehicle wheels and the road. This type instrument was later supplemented by a recording contact type accelerometer.

Another commercially available vibrograph[5], Fig. 17, suspends the mass on two lever arms which are interconnected and attached to the spring in such manner that the recorded vibrations must occur on a line intersecting the mounting pivots. Mechanical amplifications from 0.5 to 14 are provided and give a maximum natural frequency of approximately 6 cycles. Oil damping is provided with a ratio up to 8 to 1. Both magnification and damping are adjustable and calibration curves are provided to give correction factors for the various values of those two factors.

AVERAGING INDICATING VELOCITY METERS

A development of interest is the use of a magnetic pick-up so arranged that the alternating current generated, when the instrument is vibrated, is rectified and the average value indicated on a conventional direct-current meter. It is said that by the use of suitable additional electric circuits, displacement or acceleration can also be measured. Such circuits have been developed some time ago in the development of high-speed cathode-ray engine indicators. A suitable recording instrument could of course replace the indicator now used. This instrument is the type that necessitates dynamic calibration if the results of the meter indication are to be significant in terms of velocity time, acceleration time or displacement time averages.

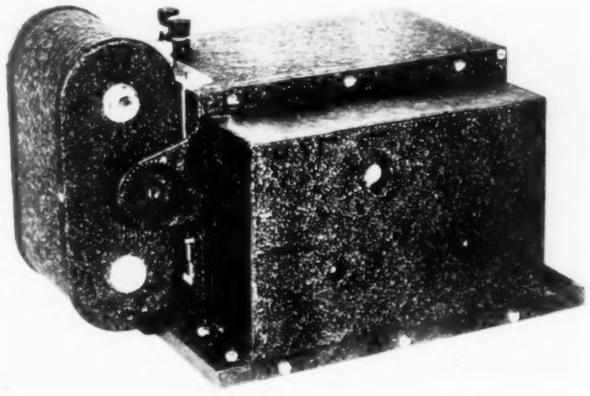


Fig. 14. Shrader Three-component Optical Recording Accelerometer.

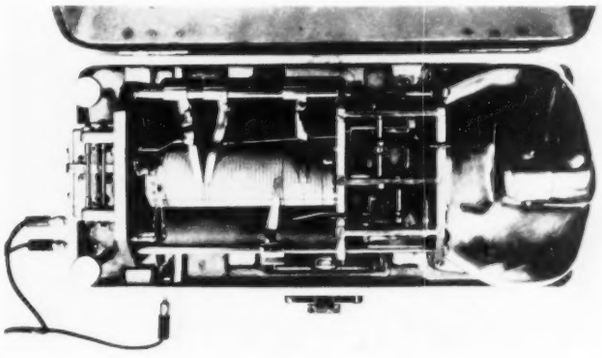


Fig. 16. R-S Three-way Ride Recorder.

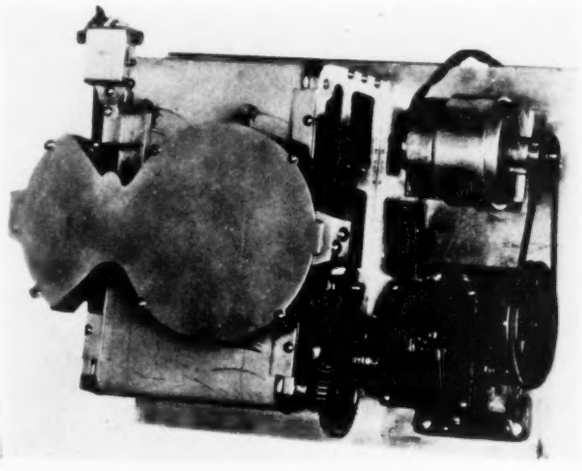


Fig. 15. Cardwell-Westinghouse Vibrograph.

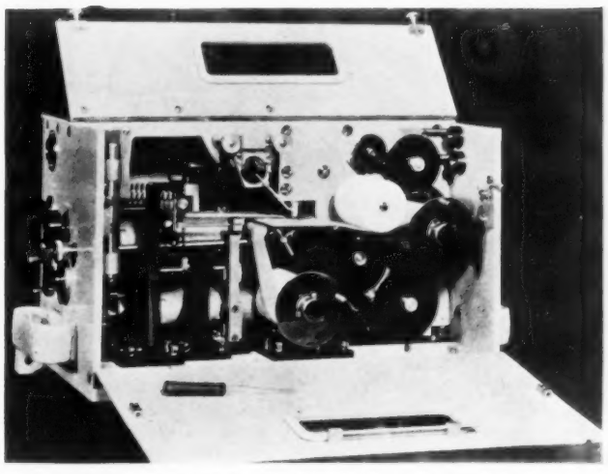


Fig. 17. Vibrograph, Ink-recording, with adjustable amplification and damping.

DISPLACEMENT MEASURING INSTRUMENTS

Displacement being the fundamental from which velocity and acceleration may be derived, it was considered early in the development of riding comfort instruments as the most prominent factor of motor car vibration which should be measured to secure a record of the vibrations occurring in motor cars. A number of seismographs[20] suitable for use in automotive vehicles have been developed. These remain useful in present-day researches.

In a study of the vibration performance of the various parts of a motor car, it may be desired to record displacement of one part relative to some other part. For example, the displacement time record of an axle in reference to the seat pan or seat cushion provides important information to the chassis development engineer. Records of displacement of the seat cushion surface in reference to the floor board

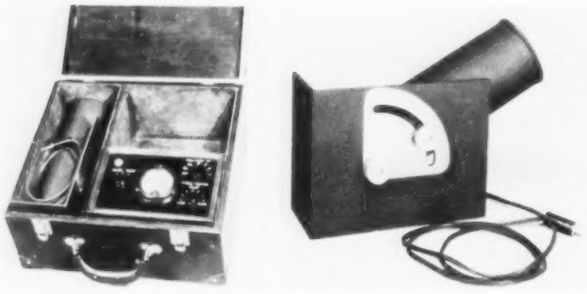


Fig. 18. The PRCA Riding Comfort Indicator. Left—Averaging indicator with controls for sensitivity, frequency and selection. Right—Vibration pick-up, adjustable through 90° angle.

or other comparatively rigid portion of the car are useful. Angular front wheel movement when the wheel is displaced vertically is another important instance where measurement of relative displacement is valuable.

Conventional chronographs designed for accurate measurement of time intervals, on account of size, fragility and narrow record width are not readily adaptable to the displacements occurring between the various part of a motor car such as mentioned above.

In Fig. 19 are illustrated two special chronographs which were developed some years ago[27] and which have proven extremely valuable in exploring relative displacements in motor cars. These are both provided with motor drive to operate from the car battery. Remote control of recording mechanism enables placing the chronograph where desired. Fast starting, stopping and constant speed of the record are provided for. These features enable convenient operation from within the car. The vertical chronograph, with continuous 10" record moving at speeds of 1" or 20" per second, is also well adapted to the making of "drop tests." Such tests however fall within the scope of instruments used in the suspension laboratory, description of which is beyond the scope of this article.

MISCELLANEOUS INSTRUMENTS

A vane type vibrometer[15] is useful in determining and isolating high-frequency low-amplitude vibrations, such as are caused by motor unbalance, gears and the like. This consists of a small case with a pointer which is placed in contact with the part where it is desired to measure the vibration. The visual intersection of the vibrating vanes determines the amplitude of the vibration.

The numerous sound measuring equipments now available can be used with vibration pick-ups of the crystal or magnetic type[23, 25], and thus an indication of the velocity frequency effect can be secured. Other types of electronic amplification mechanisms can be used instead of the sound measuring equipment. Vibration pick-ups can also be used with cathode-ray oscillographs. These instruments, dependent as they are on cyclic condition of frequencies of not less than 10 per second, are most useful for research purposes in measuring vehicle vibrations resulting from causes other than road irregularities.

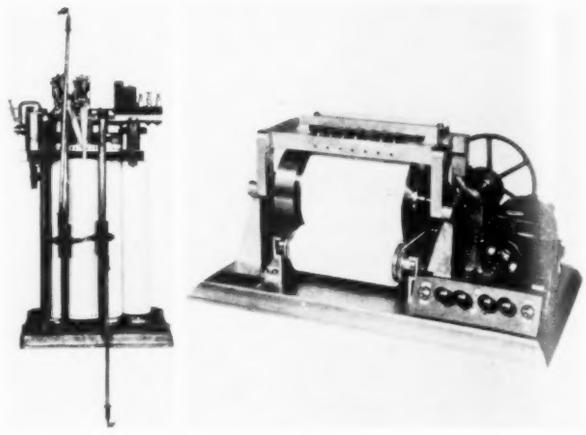


Fig. 19. Chronographs to measure displacement time characteristics of motor car vibrations. Left—This instrument has paper speeds of 1" and 20" per sec. and will measure total vertical displacement of 10". Right—Universally adjustable instrument for making horizontal records of relative displacement of car parts up to 4".

Other types of accelerometers now commercially available are the low-frequency instruments, generally without special damping provisions, used in recording decelerations due to application of brakes.[19, 20] Still another class of low frequency accelerometers, also without special damping provisions, are those developed for the airplane instrument board.[21, 22] These are usually equipped with a maximum reading hand and are calibrated from minus 1 to plus 8 gravitational units.

Recently an English riding comfort instrument,[30] recording in ink on paper, has been made commercially available. The principle of operation incorporates a gyroscope with damping "which allows drift between its elements under slow pitching to reduce the amount of pen deflection, and no drift during sharp pitching to cause full deflection." It appears that the authors have made an effort to develop an instrument, the record from which would parallel or be an index of the vibration effect on the passenger. The Riding Comfort Research Committee has seen and investigated many attempts of this type. Their work has definitely proven that the status of measurement at this time is such as to render this utopia of instrumentation a thing of the future. The instrument chart is spring-driven. The instrument is quite large and heavy and would be suitable only for use on the seat cushion. The development is definitely encouraging to the measurement of riding comfort in motor cars as it is apparent that much study has been given the design; therefore, at least a portion of the experience gained should result in improvement in some practical form.

The comfort of the motor car passenger is affected by miscellaneous secondary high-frequency vibrations such as occur from engine unbalance, operation of gears and resonance in parts of the frame and body. Numerous instruments have been made available for the measurement of similar vibrations in electric motors and the like and are useful in measuring secondary vibrations in motor cars.

A recent improvement[32] makes use of the electric current generated in a coil which is oscillated by the vibration between the poles of a permanent magnet. The generated current is amplified electronically. A suitable accessory unit is provided to integrate the indicated velocity amplitudes into displacement values. Suitable calibration units are provided for both the pick-up and amplifier units.

For some time dial-micrometers have been used in evaluating machine vibration. These have been mounted on a heavy mass and spring supported and some question has existed as to their accuracy.

The performance of such an arrangement has been recently investigated and reported upon.[33] The reference article should be consulted before any serious attempt is made to use such assembly as a vibration indicator.

While this summary of instruments developed for vibration measurement is necessarily incomplete, it is indicative that the large amount of work devoted to the instrument development problem in the past has brought forth a number of instruments capable of being successfully used by anyone reasonably skilled in the handling of commercial instruments.

The problem of measuring Riding Comfort is complex. No amount of instrumentation can change this fact. Hence it is doubtful if any simple, low-cost, rugged instrument to measure such complex conditions will be found. To get a complete picture of the complex vibration system which interferes with riding comfort, it will probably remain necessary, at least for some time to come, to make a large number of measurements under different laboratory and service conditions. The numerical value of these measurements must then be evaluated and combined into a single factor which correlates with the mental and physical effects of the vibrations to which the passenger is subjected in his normal use of the motor car.

During the past year numerous inquiries have been received concerning riding comfort instruments and technique of measuring vibration and its effect on the passenger and the vehicle structure. Replies to these inquiries have been accompanied by the mimeographed instrument summary presented two years ago. From the expressions of appreciation it is apparent that this work is proving helpful in a practical everyday manner in promoting the more exact evaluation of the complex factor entering into the riding comfort problem. Further indications of the general interest in ways and means to evaluate vibrations are the further improvement of the impedance instrument by the General Electric Company and the developments in aircraft accelerometers as indicated by the articles published in the December 1939 issue of *Instruments*: "New Applications of Variable-reluctance Method of Aircraft Instruments" by H. H. Bruderlin and "New Method of Testing Accelerometers" by B. W. Woolard.

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[19]The American Instrument Co., Silver Spring, Md.

[20]General Electric Co., Schenectady, New York.

[21]Kollsman Instrument Co., 1 Junius Street, Brooklyn, N. Y.

[22]Pioneer Instrument Co., 754 Lexington Ave., Brooklyn, N. Y.

[23]General Radio Co., Cambridge, Mass.

[24]The Brush Development Co., 3311-25 Perkins Ave., Cleveland, Ohio.

[25]D. Silverman, Measurement and Analysis of Noise and Vibration, *Instruments*, August 1939, pages 205-236. See Section 7, Vibration Measurement, page 216.

[26]See *S.A.E. Journal*, January 1920, page 17.

[27]Riding Qualities of Motor Vehicles, *S.A.E. Journal*, July 1925, pages 107-114.

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SELECTING CONTROL EQUIPMENT

(Concluded from Page 102)

DRAFT AND FLOW CONTROL

In flow control or draft control problems the process is extremely lively and the demand side energy storage is extremely small or for practical purposes does not exist. Under these conditions the draft or flow responds extremely fast to all changes and almost all the lag is controller lag. Here on-off control is entirely unsatisfactory, whereas variable-speed floating control is quite satisfactory except where rapid changes in load exist.

Positioning control may be used if the positioning range is made wide enough. However, as pointed out, almost the entire lag is controller lag and it is necessary that the positioning range be made extremely wide so as to synchronize the control speed with the process speed.

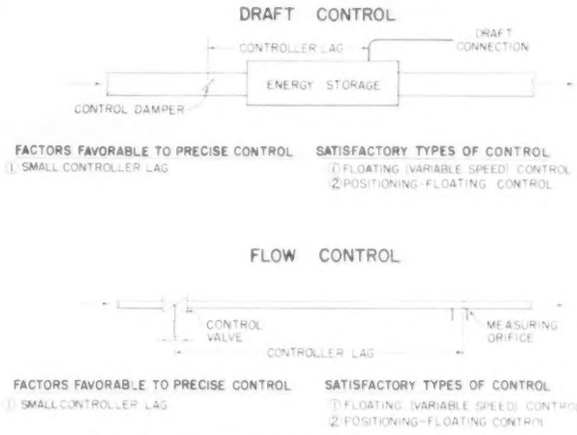

Fig. 6. Factors Affecting Draft and Flow Control.

Except for extremely steady load conditions, there is therefore little possibility of using a positioning control for this service. It is generally necessary to resort to positioning and floating control for fast accurate control.

The factors entering into the problem of draft and flow control as well as the factors favorable to precise control and the satisfactory types of control are diagrammatically summarized in Fig. 6.

CONCLUSION

From the foregoing it can be seen that most of any of the four types of controllers may be used with any process under certain operating conditions. In the final analysis, therefore, the correct application is one which will satisfy to the highest degree the requirements as to accuracy of control and ability to follow load changes.

It must be appreciated that this discussion has treated only the basic problems of control. There are a multitude of other factors specific to a given installation which must be taken into consideration in the correct application of control. Some of these are:

1. Valve or damper characteristics.
2. Controller characteristics.
3. Location of primary element with respect to process.
4. Distance between controller location and primary element location.
5. Supply pressure, temperature or B.t.u. variation.
6. Response and characteristics of auxiliary equipment such as motor, turbine, or hydraulic coupling driven fans, pumps, pulverizers, etc.

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B&L's Military Instrument Business

To the Editor of *Instruments:*

The newspaper articles concerning the indictment of Bausch & Lomb and certain of its officials have, in our opinion, been misleading. In the belief that your readers will be interested in a summary statement of the matter, we submit the following.

Bausch & Lomb Optical Co. of Rochester, N. Y., has, since 1921, held an exclusive license from Carl Zeiss, of Jena, Germany, for the use of all Zeiss patents issued in the United States covering the manufacture and sale of optical fire control instruments for military uses in this country. The contract granting such licenses also has entitled Bausch & Lomb to receive information as to the latest developments made by Zeiss in the design and manufacture of optical military instruments. Royalty payments on the part of Bausch & Lomb are provided for. The original contract made in April, 1921, was revised in 1926.

The Department of Justice has obtained indictments of Bausch & Lomb Optical Co. and three of its officers, alleging that, by reason of this contract, Bausch & Lomb has been prevented from supplying foreign governments with optical gun-fire control instruments and, further, that the contract has prevented Zeiss from supplying such instruments to the United States. It is also alleged that, as a result, Bausch & Lomb has been able to charge, and has charged, arbitrary, artificial, and unreasonably high prices for instruments sold to the United States Government.

There is no quarrel as to the underlying facts of this case, including the central facts that Bausch & Lomb has not sought foreign military business (although Zeiss has at times urged that we do so) and that the United States Government has not made Zeiss, or any other foreign concern, a source of supply for its military instruments. It is our understanding that our Government, as in the case of most major powers, has aimed to develop its own domestic sources of supply for such equipment. The operations of our military business have been built on that premise and have been regarded by us as in the nature of a joint enterprise with our Government, particularly the Navy Department for which most of our military instruments are produced. Naval officers, continuously since 1912, have been stationed at the factory in Rochester as resident inspectors of military instruments in process of manufacture and our technical staff has worked in close association with the Navy in developing gun-fire control instruments.

Viewed in the light of the foregoing, the contractual relationship with Zeiss should not be difficult to understand. In consideration of royalty payments on our part, we became entitled to receive from Zeiss technical advice and assistance in connection with the military instrument development work on which we were engaged, together with information as to the latest development work of Zeiss in that field. We also acquired an exclusive license to manufacture under all Zeiss military instrument patents in the United States and have used these rights extensively in our military instrument work. The purpose and effect of our contractual relationship with Zeiss has thus been to place at the disposal of our Government such Zeiss inventions and discoveries as were useful in the development of the Government's optical military instrument program. It has not been, as the Department of Justice charges, a means of monopolizing the domestic market. Our Government contracts result from competitive bidding with other American manufacturers who do a substantial, and we believe an increasingly large, amount of work for the Government.

The Government naturally desires diversified sources of supply and has, accordingly, assisted, and from our point of view with propriety, in the development of our domestic competitors. We have no statistical data as to the exact volume of military business done by other concerns. The indictment alleges that it has been approximately 50% of the entire domestic volume. We do not consider that such technical advantage as we have had by reason of our relationship with Zeiss has overbalanced our attendant costs which, of course, have placed us at a disadvantage in competitive bidding. During at least the last six years, the benefits derived from the Zeiss contract have been so meagre that we have made every effort to effect a reduction in royalty payments. The outbreak of the war in Europe last year has rendered further performance by Zeiss obviously impossible. The contract expires in 1941.

Under all the circumstances, we fail to see any construc- purpose which could motivate the Department of Jus- in bringing the present action and creating the im- ssion that Bausch & Lomb has entered into secret rangements with a foreign concern to mulct our own vernment by exacting "arbitrary, artificial, unreason- able, and non-competitive prices."

The prices at which we have supplied military instruments to our Government have been based solely upon our own costs and are subject to no control under the Zeiss contract. During the first ten years in which the contract was operative, our military business resulted in an accumulated net loss. During the past ten years, the average net profit on our military business has been less than 5%.

We have made no secret of our Zeiss arrangements. The Navy Department was advised of the existence of the contract within a month after its execution. A copy of the 1926 contract was handed to the Department of Justice in 1929 and became a public record when filed with the Securities and Exchange Commission in 1937.

The management of Bausch & Lomb deeply resents the imputation of unpatriotic purposes in the operation of its business. We do not believe that the attitude of the Department of Justice is shared by other Departments of the Government having an intimate knowledge of our business operations. There are in such departments men who served during the last World War and who remember the part which this Company played at that time.

From 1908 to 1915 Zeiss held approximately a one-fifth stock interest in the Company. When the World War broke out, Zeiss attempted to prevent our supplying optical equipment to the Allies. The senior generation of American stockholders, including Mr. Edward Bausch, who is now chairman of the Board of Directors, responded by repurchasing the stock held by Zeiss and continued to supply the Allies with all possible equipment.

During the period of the World War, approximately 90% of our instrument manufacturing facilities were devoted to the production of military instruments, which substantially dislocated the company's commercial instrument business for a number of years thereafter. Since then we have attempted to limit our military production to approximately ten percent of our total production.

That war found this country without any domestic source of supply for optical glass. In collaboration with representatives of the Government, the Company undertook the difficult and expensive task of developing an optical glass plant, which it has maintained and continued to develop throughout the period following the War. Today, with foreign sources of supply again shut off, the Company is prepared to take care of the resultant increased demand for this basic product.

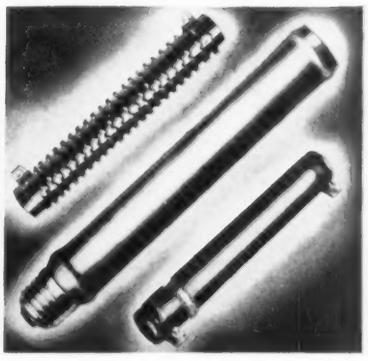
The present management of Bausch & Lomb is proud of the record which the older generation made for the Company at that time. We have been informed by officials of the Navy Department that the technical information and assistance which the Company has received from Zeiss over the years have been of great benefit to the Navy in the development of optical gun-fire control apparatus.

BAUSCH & LOMB OPTICAL CO.

Rochester, N. Y., March 30, 1940.

(EDITOR'S NOTE—Newspapers have the habit of featuring sensational accusations and later giving little space to the side of the accused. That is why we gladly print B&L's letter. It hardly needs any comment, but this incident reminds us to remind our readers that Instrumentation is an increasingly important factor in National Defense. All of us American instrumenticians—who design, install or maintain instruments, who build them or use them, who sell them or buy them, or who through printing or lectures teach the science of their use—are "auxiliary members" of the Army and Navy. Inventors, designers and builders of instruments who lessen America's dependence on foreign sources render a valuable patriotic service. In this regard, B&L has been rendering an outstanding service, according to Army and Navy technical officers who have first-hand knowledge of this firm's record during and since the First World War. Your editor—an Army Reserve officer whose duties include procurement, engineering and inspection of military instruments—knew something of this record but he did not know until he received this letter that B&L's military business resulted in an accumulated net loss in the first ten years and in less than 5% average profits in the past ten years. It seems to your editor that this is an example of unselfish patriotism.—M. F. BEHAR.)

Which Resistor ?



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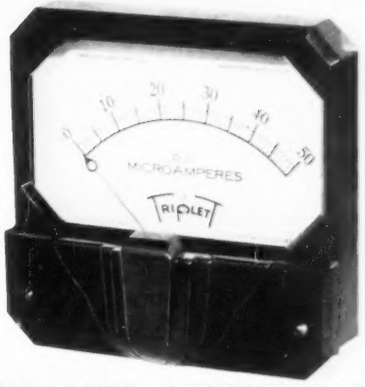

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INSTRUMENTS' BOOK SHELF

Wavelength Tables. Compiled under the direction of GEORGE R. HARRISON. The Technology Press of the Massachusetts Institute of Technology; John Wiley and Sons, New York, 1939. Cloth, 7½ × 11 inches, xxviii + 429 pages; one plate, 4 minor tables. Price $15.00.

This volume contains the M.I.T. Wavelength tables with intensities in the arc, spark, or discharge tube, of more than 100,000 spectrum lines most strongly emitted by the atomic elements under normal conditions of excitation between 10,000A and 2,000A arranged in order of decreasing wavelengths. The intensities are estimated on a scale of 1 to 9,000, and all known lines of intensity 2 are included except those arising from the third or higher state of ionization; those lying too close to stronger lines of the same element; those not previously reported.

For 75,000 lines the wavelengths are original measurements by the M.I.T. spec-spectroscopists. These wavelengths were measured by means of an automatic computating and recording comparator and many scientists have wondered about the accuracy of such a device. Your reviewer has sampled more than one percent of this great table and has found that the accuracy is as great as any hitherto attained.

This table will be invaluable to the spectroscopic analyst, especially in connection with the lines of minor constituents. The format of the book and the wide range of intensities make the table nearly as rapid to use as is the older list of one-fifth as many lines. And in addition, the weak lines are there, if required. In auxiliary tables the most sensitive lines are arranged by element, and again by wavelength. Typographical errors (one percent sampled) appear to be fewer than is common in extended wavelength tables. The excellent binding, clear type, and non-glare paper help to make this a volume which every spectroscopist will wish to have as a desk copy.

—KELVIN BURNS, *Astronomer, Allegheny Observatory, Pittsburgh.* (7.5)

Fundamental Principles of Quantum Mechanics. By EDWIN C. KEMBLE, Mc Graw-Hill Book Co., New York, 1937. Cloth, 6¼ × 9¼ inches, xviii + 611 pages. Price $6.00.

This book seems to be written not so much as a textbook for beginners, but as a guide to those who have already acquired a certain familiarity with the subject and want to penetrate deeper into the fundamental principles. Consequently, the author has endeavored to give the mathematical treatment in a much more rigid form than in most other treatises of this subject, and particularly to call attention to the difficulties and weak spots in the argument. On the other hand, the range of applications is rather limited.

The first chapter gives a historical introduction and a discussion of the ideas leading to the dualistic wave-particle theory of matter and to the Schrödinger equation. Chapters II and III deal with wave packets, energy level problems in one-dimensional systems, and the hydrogen atom. The next two chapters give the mathematical treatment of orthogonal functions and the discrete energy spectrum of the two particle problem in a central field. Chapter VI presents the theory of continuous spectra in one-dimensional systems, Chapters VII and VIII the theory of operators and related matters. Chapter IX presents a thorough discussion of the general theory of measurements, which will be most interesting for advanced students. The remaining five chapters contain Matrix theory, theory of perturbations, quantum statistical mechanics, electron spin, and the theory of the structure of many-electron atoms.

Generally speaking, the book is not easy to read, but it contains a great wealth of interesting material and thorough-going discussion of the fundamental principles of quantum mechanics. It will therefore be very useful to serious students of the subject.

—I. ESTERMANN, *Associate Professor of Physics, Carnegie Institute of Technology.*

Testing Notch Impact Toughness (Pruefung der Kerbschlagzaehigkeit). By ERICH FRANKE. Verlag Chemie, Berlin, 1939. Paper, 7 × 10½ inches, 288 pages. Price 33 RM.

This volume is the 8th edition of Gmelins Handbook of Inorganic Chemistry, Iron, Part 6, Section 2 and is a part of the subject Test Methods and Mechanical-Technological Properties of Carbon Steels as well as of Alloy Steels. This monograph on impact testing considered impact testers from the earliest to the present. The literature up to October 1938 is considered.—RICHARD RIMBACH.

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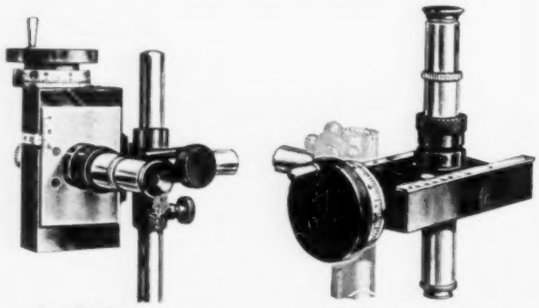

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